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INDICATION OF UNIT FACTOR INHERITANCE IN DATA COMPRISING BUT A SINGLE GENERATION

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It has been shown by Penrose (1935) that linkage between two autosomal unit characters can be detected and measured through the investigation of randomly collected pairs of brothers and sisters of unspecified parentage. This discovery promises to be of great assistance to university laboratories and similar institutions where parents are secured with difficulty. It should also prove of interest if from data of the same sort it were possible to test the hypothesis of unit factor inheritance for any human trait, and it would seem worth while, in this event, to apply such a test to both traits under investigation before proceeding with the analysis of linkage between them. Such a test, it is thought, may be accomplished by the methods to be described in this note.

Let us suppose that two characters, which we shall simply designate (+) and (−), are thought to be determined by a single pair of autosomal genes, T and t, with (+) being the dominant character. Randomly collected sibships whose parents have not been ascertained may readily be classified as to their composition and the number of each sort recorded. Now, if the population be assumed at equilibrium with respect to the distribution of genes T and t, a condition which must necessarily follow the occurrence of random mating, we may then estimate the frequencies of the two alleles. From these we may calculate the expected frequencies of the various sorts of sibship and measure the discrepancy between calculated and observed values by the usual Chi-square (χ^2) test.

USE OF SIB-PAIRS

One procedure, which has the advantage of entailing a minimum of calculations, consists in the classification of all sib-pairs

contained in the available sibships of larger size and adding these numbers to those obtained from sibships of only two members. In general, a sibship of s members must supply ${}^{s}C_2 = s(s-1)/2$ sib-pairs. However, since a χ^2-test of sibships in which the expected number in any class is less than 5 must suffer considerable inaccuracy, it is therefore advisable to exclude sibships of such sizes, rather than allow these to contribute to the three classes of sib-pairs.

Designating the frequencies of genes T and t by p and $(1-p)$, respectively, the expected proportions of sib-pairs having 0, 1, and 2 members showing the (+) character may be deduced by

TABLE I

Type of Sib-pair	Possible Genotypes of Parents	Proportional Frequency of Mating	Probability of Sib-pair	Expected Proportion of Sib-pairs
Both (—)	Tt × Tt	$4p^2(1-p)^2$	1/16	$\frac{1}{4}p^2(1-p)^2$
(tt, tt)	Tt × tt	$4p(1-p)^3$	1/4	$p(1-p)^3$
	tt × tt	$(1-p)^4$	1	$(1-p)^4$
(+) and (—) (TT, tt)	Tt × Tt	$4p^2(1-p)^2$	6/16	$\frac{3}{2}p^2(1-p)^2$
or (Tt, tt)	Tt × tt	$4p(1-p)^3$	1/2	$2p(1-p)^3$
Both (+) (TT, TT)	TT × TT	p^4	1	p^4
	TT × Tt	$4p^3(1-p)$	1	$4p^3(1-p)$
or (TT, Tt)	TT × tt	$2p^2(1-p)^2$	1	$2p^2(1-p)^2$
or	Tt × Tt	$4p^2(1-p)^2$	9/16	$\frac{9}{4}p^2(1-p)^2$
(Tt, Tt)	Tt × tt	$4p(1-p)^3$	1/4	$p(1-p)^3$

application of the principle of random mating as is shown in Table I. The expectations in the three classes are found by summing the terms in the extreme right-hand column for each type of sib-pair. In a sample of n_2 sib-pairs the expected frequencies of sib-pairs having 0, 1, and 2 (+) members are therefore, respectively,

$$\left.\begin{aligned} f_{20} &= \tfrac{1}{4}(1-p)^2(2-p)^2 n_2, \\ f_{21} &= \tfrac{1}{2}p(1-p)^2(4-p)n_2, \\ \text{and} \quad f_{22} &= \tfrac{1}{4}p(4+5p-6p^2+p^3)n_2. \end{aligned}\right\} \quad \ldots\ldots\ldots (1)$$

The most convenient means of obtaining an estimate of p is by employing the observed proportions of (+) and (−) individuals in the aggregate of the sibships used in the χ^2-test. The expected proportions of (+) and (−) individuals under random mating are $1-(1-p)^2$ and $(1-p)^2$, respectively, and if the corresponding observed proportions are A and B, we may then take

$$p=1-\sqrt{B}. \qquad \ldots\ldots\ldots(2)$$

Using this estimate we may calculate the expected frequencies (1) of the three sib-pair types and compare these with the observed numbers by the method of Chi-square. The number of degrees of freedom to use in entering a probability table of χ^2 values is one (1) in this case, in accordance with the fact that the expected values are adjusted so as to conform with the observed series in two respects—the total number, n_2, and the parameter, p.

TABLE II

Type of Sibship	Possible Genotypes of Parents	Proportional Frequency of Mating	Probability of Sibship	Expected Proportion of Sibships
All s (−)	Tt × Tt	$4p^2(1-p)^2$	$(\frac{1}{4})^s$	$4(\frac{1}{4})^s p^2(1-p)^2$
s(tt)	Tt × tt	$4p(1-p)^3$	$(\frac{1}{2})^s$	$4(\frac{1}{2})^s p(1-p)^3$
	tt × tt	$(1-p)^4$	1	$(1-p)^4$
r (+), s-r (−) r(TT,Tt)	Tt × Tt	$4p^2(1-p)^2$	${}^sC_r(\frac{3}{4})^r(\frac{1}{4})^{s-r}$	$4\,{}^sC_r(\frac{3}{4})^r(\frac{1}{4})^{s-r}p^2(1-p)^2$
s-r(tt)	Tt × tt	$4p(1-p)^3$	${}^sC_r(\frac{1}{2})^s$	$4\,{}^sC_r(\frac{1}{2})^s p(1-p)^3$
All s (+) s(TT,Tt)	TT × TT	p^4	1	p^4
	TT × Tt	$4p^3(1-p)$	1	$4p^3(1-p)$
	TT × tt	$2p^2(1-p)^2$	1	$2p^2(1-p)^2$
	Tt × Tt	$4p^2(1-p)^2$	$(\frac{3}{4})^s$	$4(\frac{3}{4})^s p^2(1-p)^2$
	Tt × tt	$4p(1-p)^3$	$(\frac{1}{2})^s$	$4(\frac{1}{2})^s p(1-p)^3$

USE OF SIBSHIPS OF LARGER SIZE

A more extensive treatment of the data might be undertaken by comparing the observed frequencies of the various sorts of trios, quartettes, quintettes, etc., with the frequencies expected under random mating. In general, for sibships of size s, the expected proportions of each of the (s+1) different sorts may be derived as shown in Table II. The expected frequencies in the three classes indicated in the table are found by summing

the terms in the right-hand column for each class and multiplying by n_s, the observed number of sibships of s. The expected number of sibships having all s members of the (+) type is

$$f_{ss}=\{p^4+4p^3(1-p)+(2+3^s4^{1-s})p^2(1-p)^2+2^{2-s}p(1-p)^3\}n_s, \quad \ldots\ldots\ldots(3)$$

and the expected number having no (+) members is

$$f_{so}=\{4^{1-s}p^2(1-p)^2+2^{2-s}p(1-p)^3+(1-p)^4\}n_s$$
$$=\left\{(1-p)\left[1-p\left(\frac{2^{s-1}-1}{2^{s-1}}\right)\right]\right\}^2 n_s, \quad \ldots\ldots\ldots(4)$$

while for the remaining (s−1) types, the expectations can be calculated from the expected number of sibships having r (+) and s−r (−) members,

$$f_{sr}=\{4^sC_r(3/4)^r(1/4)^{s-r}p^2(1-p)^2+4^sC_r(1/2)^sp(1-p)^3\}n_s$$
$$={}^sC_rp(1-p)^2\left\{p\frac{3^r}{4^{s-1}}+(1-p)\frac{1}{2^{s-2}}\right\}n_s, \quad \ldots\ldots\ldots(5)$$

which is general except for the cases, r=0 and r=s.

TABLE III

Polynomials for Computing the Expected Proportions of Various Sibship Classes

Class		Coefficient of				
s	r	1	p	p^2	p^3	p^4
2	0	4	−12	13	−6	1
2	1		8	−18	12	−2
2	2		4	5	−6	1
3	0	16	−56	73	−42	9
3	1		24	−63	54	−15
3	2		24	−45	18	3
3	3		8	35	−30	3
4	0	64	−240	337	−210	49
4	1		64	−180	168	−52
4	2		96	−234	180	−42
4	3		64	−84	−24	44
4	4		16	161	−114	1
5	0	256	−992	1441	−930	225
5	1		160	−465	450	−145
5	2		320	−870	780	−230
5	3		320	−690	420	−50
5	4		160	−75	−330	245
5	5		32	659	−390	−45

Expressions (3), (4), and (5) are polynomials in p of the 4th degree. For the purpose of simplifying calculations the coefficients of each term have been computed and set out in Table III for the various sorts of sibships of 2, 3, 4, and 5 members. The expected frequency in any class may be found by summing the terms containing the appropriate coefficients, dividing the sum by the quantity, $2^{2(s-1)}$, and multiplying by the total number of sibships of that size. For example, the expected number of trios having 1 (+) member and 2 (−) members is

$$f_{31} = \frac{n_3}{16}(24p - 63p^2 + 54p^3 - 15p^4).$$

Separate estimates of p may be calculated from the proportions of (+) individuals among sibships of each size or a single estimate may be obtained from the proportion found among sibships of all sizes. In the first case, a χ^2-test of sibships of size s will involve $s-1$ degrees of freedom and χ^2 may thus be calculated for each size of sibship separately. When a single value of p is used χ^2 may be calculated for the entire data and the number of degrees of freedom will be one less than the sum of all values of s.

ALTERNATIVE HYPOTHESES

An important limitation of the method described above is the fact that, except for very extensive data, it should not generally be possible to distinguish whether (+) or (−) is actually the dominant trait, even when the hypothesis of unit factor inheritance has been confidently established. This may be demonstrated in a general way as follows: If, instead of assuming (+) to be the dominant character as in the above analysis, we should assume (+) to be the recessive trait, than we might estimate the frequency of the dominant gene as

$$p' = 1 - \sqrt{A}, \qquad \ldots\ldots\ldots (6)$$

and the expected frequencies of sibships of 0, 1 and 2 (+) members would then be the reverse of those given in (1), that is,

$$\left.\begin{aligned} f'_{20} &= \tfrac{1}{4}p'(4 + 5p' - 6p'^2 + p'^3)n_2, \\ f'_{21} &= \tfrac{1}{2}p'(1 - p')^2\,(4 - p')n_2, \\ f'_{22} &= \tfrac{1}{4}(1 - p')^2\,(2 - p')^2 n_2, \end{aligned}\right\} \qquad \ldots\ldots\ldots (7)$$

or, substituting the estimate p' given by (6),

$$\left.\begin{aligned} f'_{20} &= \{1-\tfrac{1}{2}A(1-\sqrt{A})\ (3+\sqrt{A})-\tfrac{1}{4}A(1+\sqrt{A})^2\}n_2, \\ f'_{21} &= \tfrac{1}{2}A(1-\sqrt{A})\ (3+\sqrt{A})n_2, \\ f'_{22} &= \tfrac{1}{4}A(1+\sqrt{A})^2 n_2. \end{aligned}\right\} \quad \ldots(8)$$

These are to be compared with

$$\left.\begin{aligned} f_{20} &= \tfrac{1}{4}(1-A)\ (1+\sqrt{1-A})^2 n_2, \\ f_{21} &= \tfrac{1}{2}(1-A)\ (1-\sqrt{1-A})\ (3+\sqrt{1-A})\ n_2, \\ f_{22} &= \{1-\tfrac{1}{2}(1-A)\ (1-\sqrt{1-A})\ (3+\sqrt{1-A})-\tfrac{1}{4} \\ &\qquad (1-A)\ (1+\sqrt{1-A})^2\}n_2, \end{aligned}\right\} \quad \ldots(9)$$

the values expected where (+) is dominant, found by putting $p=1-\sqrt{1-A}$ in the expressions in (1).

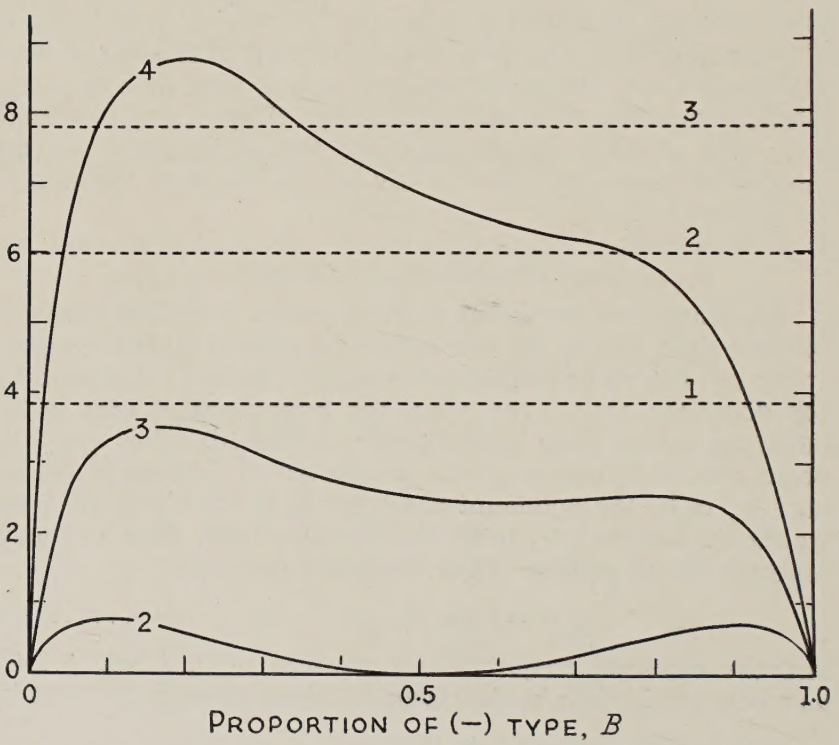

FIG. 1. Expected values of χ^2 as a measure of discrepancy between sibship expectations under the assumptions of dominance of (+) and of (—) types, calculated on the basis of 100 sibships each of 2, 3, and 4 sibs. Compare with the 5 per cent levels of significance for 1, 2, and 3 degrees of freedom, shown by broken lines.

We may get some idea as to the relative chances of eliminating the hypothesis of dominance for the (−) trait by assuming the observed frequencies to be consistent with the expectations of dominance for the (+) trait and by calculating the expected value of χ^2 as a measure of the discrepancies between corresponding expectations under the two hypotheses. The quantity,

$$\chi^2 = S\left\{\frac{(f'sr - fsr)^2}{f'sr}\right\},$$

is plotted in Figure 1 for values of B from 0 to 1 and for sibships of two, three, and four members, using 100 sibships of each size. The results show that sibships of larger size are more valuable in attempting to discriminate between the two hypotheses, but that considerably larger numbers should be available even in these cases.

TABLE IV

Expected values of χ^2 as a measure of discrepancy between sib-pair expectations under the assumptions of unit factor inheritance with (+) as the dominant trait and of non-genetic chance determination, calculated on the basis of 100 sib-pairs.

Proportion of (—) type, B	χ^2	Proportion of (—) type, B	χ^2
0	0	0.6	21.89
0.1	13.77	0.7	22.95
0.2	16.40	0.8	23.64
0.3	18.29	0.9	24.34
0.4	19.76	1.0	0
0.5	20.92		

In the investigation of a trait heretofore unstudied from the genetic standpoint it might be desirable to eliminate, if possible, another hypothesis, namely, that the difference between (+) and (−) types is attributable to chance agencies in which biological relationship plays no part. Under this supposition, however, we should expect the various sorts of sibships of s to occur with frequencies which are the terms in the expansion of the binomial,

$$(A + B)^s n_s.$$

Comparing these expectations with those based upon the assumption of unit factor inheritance by calculating χ^2 as before we have the values listed in Table IV, in which 100 sibships of two members are assumed to be available. The table shows

that we may be quite confident of eliminating an hypothesis of non-genetic chance determination if the data are, in fact, consistent with expectations under the hypothesis of unit factor inheritance.

APPLICATION TO DATA ON "P. T. C." TASTE DEFICIENCY

For the purpose of illustrating the χ^2-test of sibships by a numerical example, we may test a body of data on phenylthiocarbamide taste deficiency. Crystals of "P. T. C." were used in making these tests, and most of the families recorded consisted of sibs whose parents were not tested. Utilizing those families in which both parents were tested, however, we may, as a preliminary measure, test the hypothesis of random mating with respect to this character. A simple procedure for this purpose consists in the use of a two-by-two table in which members of either sex are classified as to their own taste reactions and as to the taste reactions of their mates. A significant deviation from proportionality in the four combination classes may then be taken as indicative of assortative mating or the absence of random mating.

Since ability to taste has previously been shown (Blakeslee and Salmon, 1931; Snyder, 1931) to be the dominant trait, we may designate tasters by (+) and non-tasters by (−). In the 78 families having both parents tested the observed frequencies of the four parental combinations are as shown in the following table:

TABLE V

43	17	60	+	wives
13	5	18	−	wives
56	22	78		total
+	−			
husbands		total		

The entries are almost exactly proportional to the marginal frequencies as should be expected under random mating. The value expected in the class in which both parents are non-tasters is $(22 \times 18)/78 = 5.077$. Calculation of the probability of a departure from expectation equal to or greater than the one

observed is as follows (cf. Fisher, p. 99): The observed set of entries and those more extreme in their deviation from proportionality in the same direction are

$$\begin{bmatrix} 43 & 17 \\ 13 & 5 \end{bmatrix}, \begin{bmatrix} 42 & 18 \\ 14 & 4 \end{bmatrix}, \begin{bmatrix} 41 & 19 \\ 15 & 3 \end{bmatrix}, \begin{bmatrix} 40 & 20 \\ 16 & 2 \end{bmatrix}, \begin{bmatrix} 39 & 21 \\ 17 & 1 \end{bmatrix}, \begin{bmatrix} 38 & 22 \\ 18 & 0 \end{bmatrix}$$

and their respective probabilities are

$$\left(\frac{60!18!56!22!}{78!}\right) \quad \left(\frac{1}{43!17!13!5!}, \frac{1}{42!18!14!4!}, \frac{1}{41!19!15!3!}, \frac{1}{40!20!16!2!}, \frac{1}{39!21!17!}, \frac{1}{38!22!18!}\right),$$

or, 0.2341, 0.1998, 0.1177, 0.0453, 0.0101, 0.0010. The observed set of entries is therefore to be expected by chance in over 23 per cent of trials and deviations from proportionality in the direction observed of equal or greater magnitude should be obtained in as much as 60 per cent of trials. The assumption of random mating is thus highly justified.

TABLE VI

Numbers of cases of various sibships of 2, 3, and 4 sibs tested for "P. T. C." taste deficiency

Size of Sibship, s	Number of Tasters, r					Totals, n_s
	0	1	2	3	4	
2	11	22	74	..	..	107
3	8	8	16	38	..	70
4	1	5	7	8	16	37

The observed frequencies of the various sorts of sibships of 2, 3, and 4 members are given in Table VI. Larger sibships were also contained in the data but were few in number and no analysis of them shall be attempted.

The total number of tasters in sibships of any size, s, is found by summing the quantity r (n_{sr}) for all values of r. For example, among sib-pairs the total number of tasters is $(0\cdot11+1\cdot22+2\cdot74) = 170$, the total number of individuals among sib-pairs is $sn_s = 2\cdot107 = 214$, and the proportion of tasters in sibships of 2

is therefore $A = 170/214 = 0.7943925$, giving $p = 1 - \sqrt{1-A} = 0.5466$. The values of A and p calculated in a similar manner from sibships of 3 and 4 are shown in Table VII.

TABLE VII

Values of A and p indicated by sibships of 2, 3, and 4 sibs

Size of Sibship, s	Total Number of Tasters	Total Number of sibs, sn_s	Proportion of Tasters, A	p $(=1-\sqrt{1-A})$
2	170	214	.7943925	.5466
3	154	210	.7333333	.4836
4	107	184	.7229729	.4737

TABLE VIII

Calculation of the Expected Frequencies

Class s	Class r	k_0p^0	k_1p^1	k_2p^2	k_3p^3	k_4p^4	$\sum_{i=0}^{4} k_ip^i$	Expected Frequency $f_{sr} = \frac{n_s}{2^{2(s-1)}} \sum_{i=0}^{4} k_ip^i$
2	0	4	—6.5592	3.8844	—.9798	.0893	.4347	11.6282
2	1		4.3728	—5.3784	1.9596	—.1786	.7754	20.7420
2	2		2.1864	1.4940	—.9798	.0893	2.7899	74.6298
			p = .4836	p^2 = .2339	p^3 = .1131	p^4 = .0547		
3	0	16	—27.0816	17.0747	—4.7502	.4923	1.7352	7.5915
3	1		11.6064	—14.7357	6.1074	—.8205	2.1576	9.4395
3	2		11.6064	—10.5255	2.0358	.1641	3.2808	14.3535
3	3		3.8688	8.1865	—3.3930	.1641	8.8264	38.6155
			p = .4737	p^2 = .2244	p^3 = .1063	p^4 = .0504		
4	0	64	—113.6880	75.6228	—22.3230	2.4696	6.0814	3.5158
4	1		30.3168	—40.3920	17.8584	—2.6208	5.1624	2.9845
4	2		45.4752	—52.5096	19.1340	—2.1168	9.9828	5.7713
4	3		30.3168	—18.8496	—2.5512	2.2176	11.1336	6.4366
4	4		7.5792	36.1284	—12.1182	.0504	31.6398	18.2918

The expected frequencies of the various sorts of sibships of 2, 3, and 4 are calculated in Table VIII. The coefficients, k_0–k_4, are obtained from Table III and the values of p used for each sibship size are those given in Table VII.

Two classes of quartettes (0 and 1 taster) have expected frequencies which are less than 5 and it is customary to combine such classes in the χ^2-test, using one less degree of freedom, as shown in Table IX.

TABLE IX

Calculation of χ^2 for sibships of each size and for the total

Class s	Class r	Observed Frequency, n_{sr}	Expected Frequency, f_{sr}	$\frac{(f_{sr}-n_{sr})^2}{f_{sr}}$	χ^2	Degrees of Freedom	Probability, P
2	0	11	11.6282	.034	.115	1	.74
2	1	22	20.7420	.076			
2	2	74	74.6298	.005			
3	0	8	7.5915	.002	.441	2	.80
3	1	8	9.4395	.220			
3	2	16	14.3535	.189			
3	3	38	38.6155	.010			
4	0, 1	6	6.5003	.039	.968	2	.62
4	2	7	5.7713	.262			
4	3	8	6.4366	.380			
4	4	16	18.2918	.287			
Totals		.....	.....	.....	1.524	5	.92

The observed values conform very closely with the expected series, though not unreasonably so, and the hypothesis of unit factor inheritance with the ability of taste as the dominant character is therefore substantially upheld.

TABLE X

Sib-pairs available in sibships of 2 and 3 sibs

Number of Tasters, r	Sib-pairs in Sibships of 2	Sib-pairs in sibships of 3 in which tasters number				Total, n_{2r}
		0	1	2	3	
0	11	24	8	..	..	43
1	22	..	16	32	..	70
2	74	..	..	16	114	204
Total.....	107	24	24	48	114	317

As an alternative procedure we may take all of the sib-pairs contained in the sibships of 3 and combine the numbers of each

type with those obtained from sibships of 2 only. The sibships of 4 are not used in like manner, since the expected numbers in two classes are less than 5. The 8 trios having no (+) members provide 24 pairs having no (+) members, the 8 trios of 1 (+) member provide 8 pairs of no (+) members and 16 pairs of 1 (+) member, etc. The total contributions of sib-trios to the three sib-pair classes are shown in Table X.

The number of tasters in sib-pairs and trios combined is $170+154=324$, as shown in Table VII, among a total number of individuals, $214+210=434$, giving as the proportion of tasters in sibships of 2 and 3 combined the fraction, $A=324/424$, and the value of p indicated by sibships of both sizes is therefore

$$p=1-\sqrt{1-\frac{324}{424}}=.514357.$$

The expected numbers of sibships having 0, 1, and 2 (+) members are calculated from equations (1), which give

$$f_{20}=41.2535,$$
$$f_{21}=67.0213,$$
$$f_{22}=208.7252.$$

Comparing these with the observed values, 43, 70, and 204, χ^2 is found to be 0.313, which for one degree of freedom should be exceeded by chance in about 60 per cent of trials. The data are again in good agreement with the hypothesis of unit factor inheritance with ability to taste as the dominant trait.

To test the hypothesis that the absence of taste (−) is dominant we may test the sib-pair frequencies obtained from sibships of 2 and 3 in a similar manner, as described in the foregoing section. In this case the expected frequencies as calculated from equations (8) turn out to be

$$f_{20}=45.2394,$$
$$f_{21}=59.0500,$$
$$f_{22}=212.7106,$$

and χ^2 is 2.499. The deviations are greater than those calculated under the assumption of dominance for taste ability but are not significant in themselves. With one degree of freedom one should expect a χ^2 value of 2.499 to be exceeded by chance in 12 per cent of trials. It thus appears impossible to determine from the data whether tasters or non-tasters are dominant by this method, as might have been expected. Unit factor inheritance of one sort or the other, however, may be confidently assumed.

The hypothesis that ability to taste phenyl-thiocarbamide is determined by non-genetic chance agencies can readily be eliminated. The expected frequencies of sib-pairs containing 0, 1, and 2 tasters under this assumption are, respectively,

$$B^2n_2=\left(\frac{100}{424}\right)^2\times 317=17.6347,$$

$$2ABn_2=2\times\frac{324}{424}\times\frac{100}{424}\times 317=114.2595,$$

and

$$A^2n_2=\left(\frac{324}{424}\right)^2\times 317=185.1058.$$

Comparing these with the observed numbers, 43, 70, and 204, χ^2 is found to be 55.558, which for one degree of freedom should be exceeded in far less than once in 1000 trials.

SUMMARY

Randomly collected sibships of unspecified parentage may be classified as to their composition and the expected frequency of each sibship type may be calculated from the total number of sibships of each size and from the proportions of the two types of individuals in such sibships. The observed frequencies may then be compared with the expected values by the method of Chi-square. With small numbers of sibships, however, it will usually be impossible to determine which of the two contrasting characters is actually dominant by such a χ^2-test. If the observed frequencies agree satisfactorily with expectations under an hypothesis of dominance for one character, it may usually be expected that they shall not deviate significantly from expectations under an hypothesis of dominance for the contrasting character. It will usually be possible, however, to eliminate an hypothesis of non-genetic chance determination, if the data are in agreement with the hypothesis of unit factor inheritance.

Applying the χ^2-test to randomly collected sibships tested for taste deficiency to phenyl-thiocarbamide these generalizations are found to hold true. The data are in excellent agreement with the unit factor hypothesis established by Blakeslee and Salmon and by Snyder.

The Chi-square method should be useful as a check of unit factor inheritance in data which are to be analyzed for autosomal

linkage by the method of Penrose and as a preliminary genetic test in the case of new reaction differences.

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THE PORTERSVILLE MEMBER OF THE CONEMAUGH FORMATION IN MUSKINGUM COUNTY, OHIO

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The problem on which this paper reports progress concerns the Portersville member of the Conemaugh Formation in Muskingum County. To quote from Condit's bulletin on the Conemaugh Formation in Ohio, the Portersville is usually found as "a black calcareous shale, rich in pyrite and carbonaceous matter and often containing masses of fossils preserved as pyrite. In some places a layer of black nodular limestone overlies the shale, beautifully preserved fossils occur, the fauna being especially rich in minute pelecypods and gastropods."[1] The object of this investigation was to study the fauna to see if there are any significant differences in the fauna found in different localities.

As a result of a field study of the member, collections of fossils were made in eight different localities in this region and carefully studied. In two of these Coal Hollow located in the southwest part of section 22 in Bluerock Township, and Norwich located in the northwest part of section 7 in Union Township about twelve miles north of Coal Hollow, I found the best preserved and most abundant fauna. Therefore more time was spent on these faunas and consequently much of the discussion in this paper will concern these two localities.

These two places had some fossils in common but in many cases the forms which would be abundant in one would not be abundant in the other. The forms which were found to be abundant in both localities are:

Crinoid stems
Chonetes verneuilanus
Derbya crassa

Two of these three forms which are abundant in both localities are the brachiopods, *Chonetes verneuilanus* and *Derbya crassa*, which are fairly abundant throughout the whole region not only in this horizon but in others. There are only two other forms which are found in both localities, a species of *Worthenia* and *Orthaceras rushense;* both of these forms are abundant at

[1]Condit, Geological Survey of Ohio, Fourth Series Bulletin No. 17, p. 276.

Norwich but scarce at Coal Hollow. Farmers near Coal Hollow digging for underlying Anderson coal report the finding of coiled cephalopods, a species of which I report for Norwich.

The forms which are found at Coal Hollow but which are not reported for the Norwich section are:

Rhombopora lepidodrendroides
Chonetes granulifer
Chonetes granulifer var. *armata*
Productus cora (of authors)
Astartella vera
Edmondia aspenwallensis
Leda bellistriata
Nuculopsis ventricosa
Parallelodon obsoletus
Parallelodon tenuistriatus
Pharkidonotus percarinatus
Plant remains

Of these twelve forms, it is significant that six of them are pelecypods while in the Norwich section there are no pelecypods found at all. Inasmuch as *Chonetes granulifer* and *Chonetes granulifer* var. *armata* have not been reported for this horizon before I shall describe them briefly. The specimens in nearly all cases have been preserved as pyrite or marcasite.

1892. *Chonetes coronata* Conrad, Hall, Nat. Hist. of N. Y. Pal., Vol. VIII, Part I, p. 303, Pl. xvi, figs. 10, 11.

Hamilton group, Darien, N. Y.

1912. *Chonetes granulifer* Owen, Condit, Conemaugh Formation in Ohio, p. 300–301, Pl. XIII, fig. 3.

Ames limestone, New Concord, Ohio.

Chonetes granulifer upon superficial examination could easily be mistaken for *Chonetes verneuilanus*. There are, however, several outstanding differences. *C. granulifer* has a broad, shallow mesial sinus on the pedicle valve, while *C. verneuilanus* has a rather deep mesial sinus on the pedicle valve. Growth lines also seem to be more pronounced on *C. granulifer* than on *C. verneuilanus*. The hinge line of *C. granulifer* appear to be shorter and beak not so elevated as on *C. verneuilanus*. On the whole, *C. granulifer* appears to be somewhat smaller in size than *C. verneuilanus*. The dimensions of an average individual are length of hinge lines, 9 mm. and height, 7 mm.

1915. *Chonetes granulifer* var. *armatus* Girty, Wewoka Formation of Okla., p. 62, Pl. VII, fig. 2–4.

Wewoka formation, Oklahoma.

While I found only two specimens of *Chonetes granulifer* var. *armata*, I think they are distinctive enough to be placed provisionally

in this classification. They differ from *C. granulifer* in that they possess numerous small spine bases located in no particular order over the shell but follow roughly the plications running outward from the beak to the edge of the shell. On one specimen there is a fairly pronounced mesial sinus while on the other this sinus is broad and rather shallow as on a true *C. granulifer*. In neither case was the beak as high as that of *Chonetes verneuilanus*. On both specimens the hinge line was extended so that there were little ear-like projections on either end of the hinge line. The dimensions of these specimens were:

hinge line 7 mm.	length 4 mm.
8 mm.	5 mm.

On the other hand, the forms which are found at Norwich constitute a somewhat different type of fauna, which consists of brachiopods and cephalopods instead of brachiopods and pelecypods as at Coal Hollow. These forms which are found at Norwich but not at Coal Hollow are:

Lophophyllum profundum
Ambocoella planoconvexa
Orbiculoidea missouriensis
Spirifer cameratus
Schizostoma catilloides
Orthaceras sp.
Temnocheilus forbesianus

The species *Orthaceras rushense* McChesney is abundant at Norwich but is found only occasionally at Coal Hollow. The form *Ambocoelia planoconvexa* is very abundant here and could be called the dominant form in spite of the fact that it is somewhat undersize as compared with forms taken from other formations.

Between the localities of Coal Hollow and Norwich, there is a locality, the Eckleberry farm, the fossils of which have been reported in Condit's Bulletin on the Conemaugh Formation.[2] This farm is located in section 10 of Bluerock Township, 2½ miles north of Coal Hollow and 12½ miles southwest of Norwich. Here are found twenty-five forms reported, four of which are found in both of the other localities mentioned. These four are:

Crinoid fragments
Derbya crassa
Chonetes verneuilanus
Orthaceras rushense

[2]Op. cit., pp. 276–277.

SUMMARY OF FAUNAL DISTRIBUTION

	Coal Hollow	Norwich	Section 1	Section 6	Section 8	Section 10	Section 12	Section 13	
Lophophyllom profundum		aa	r(?)						
Crinoid stems	a	a	r	r		r	r	a	
Rhombopora lepidodendroides	a								
Ambocoelia planoconvexa		aaa				r	r		
Chonetes granulifer	a								
Chonetes granulifer armata	r								
Chonetes verncuilanus	aa	a	r	r					
Derbya crassa	aaa	aa	a	a	a	a	r	a	
Orbiculoidea Missouriensis		r							
Productus cora (of authors)	aa								
Spirifer cameratus		r			r(?)				
Astartella vera	r								
Edmondia aspenwallensis	a		r	r	a	a	r(?)	a	
Leda bellistriata	a				a			r	
Nuculopsis ventricosa	r								
Paralledodon obsoletus	r								
Parallelodon tenuistriatus	a			r	r				
Pharkidonotus percarinatus	a		r	a					
Pleurotomaria carbonaria					r	r(?)	a		
Schizostoma catilloides		r							
Worthenia sp.	r	a	r		r	r		r(?)	
Orthaceras sp.		r							
Orthaceras rushense	r	a							
Temnocheilus forbesianus		r							
Plant remains	r								

a = abundant.
aa, aaa = very abundant.
r = rare.
r(?) = questionably present.

Three of the forms found at this section are found only at Norwich but not at Coal Hollow. Six of the forms found are common to both Coal Hollow and the Eckleberry farm but not to Norwich. These forms are *Rhombopora lepidodendrendes*, *Productus cora* (of authors), *Edmondia aspenwallensis*, *Nuculopsis ventricosa*, *Leda bellistriata*, and *Astartella vera*. This horizon at the Eckelberry farm contains a number which are not found in either of the other localities. There are also six different types found here that are not reported for the type section at Portersville, in Perry County, about 15 miles southwest of Coal Hollow.

From this evidence we are bound to notice several salient facts. First, the faunas found in these three localities differ in several respects.

Second, the fauna found in Coal Hollow seems to be one containing brachiopods with an abundance of pelecypods and a sprinkling of other forms including one bryozoan. The fauna found at Norwich is one containing brachiopods, gastropods and cephalopods but no pelecypods. The Norwich collection also contains many specimens of the coral *Lophophyllum profundum* which may or may not be significant. The species found in the Eckleberry fauna appear to be more closely related to the forms found in Coal Hollow than to those found at Norwich. However, there are enough of the Norwich forms found to classify this fauna as one which is intermediate between Coal Hollow and Norwich. Evidently some of the Norwich forms reached this far south but did not get as far as Coal Hollow and vice versa. The number of species found in these three localities is far less than the number found in the type section at Portersville in Perry County. The faunas of these localities also seem to contain a much more predominantly brachiopod fauna than Condit reports for the type section. However, these variations might be due to differences in the living conditions in the different localities.

Third, the fauna varies so much from locality to locality, that it would be difficult to identify the number by means of its fossils alone.

In comparing the size of the species in this horizon with that of the same species in other horizons as reported in the literature, it is found that some of the forms are undersize while others are larger than usual. Three of the pelecypods found at Coal Hollow are undersize, two are normal, and one is larger than the

dimensions commonly given for an average individual of that species. The forms which are abundant in both localities, *Chonetes verneuilanus* and *Derbya crassa*, are the normal size according to the dimensions given for these two species. Of the seven different forms found only at Norwich, four are of average size, one, *Lophophyllum profundum*, is larger than usual, and two are smaller than the dimensions given. One of these latter is *Ambocoelia planoconvexa*, which is by far the most abundant species at Norwich, is distinctly below normal in size.

THE URINARY ELIMINATION OF BORIC ACID

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In the use of "Metheneamine" ("Hexamethylenetetramine," "Urotropine") as a urinary antiseptic, some acid is customarily administered to maintain the acidity of the urine. Boric may be and is frequently used for this purpose. However, boric acid and borates are not without physiological effect when administered in sufficiently large amounts and if elimination does not proceed promptly, and accumulation takes place because of the slowness of elimination, toxic effects may result. Instances of harm arising from boric acid and borates are recorded in the literature (1). Schattenfroh states (2): "Undoubtedly the use of boric acid and borates is fraught with danger." Their use as preservatives in foods and food products is forbidden because of the belief that their presence in the foods that are consumed would be prejudicial to health.

Voicu (3) has shown that the toxicity of boric acid to organisms that produce ammonia from urea is lowered one-third by the presence of a two per cent glucose solution. The presence of glucose in the blood stream can conceivably decrease the toxicity of borates and boric acid in the body. The glucose may react with boric acid in the same manner as does the mannitol that is used in the titration method for its quantitative estimation.

With these facts in mind the authors have undertaken to study the rate of elimination of boric acid through the urinary tract.

METHODS

The titration method is the most convenient means for the quantitative determination of boric acid, and is sufficiently reliable for use when certain precautions are observed. These precautions consist in the main in the treatment of the boron containing sample with a mineral acid to a definite acidity, titration with a standard alkali solution to a known pH in the presence of an indicator, the addition of a weighed amount of mannitol and titration to a definite color change of the indicator after the addition of the mannitol. The alkali is usually standardized in terms of boric acid by check against samples of known boric acid content.

Biltz and Marcus (4) concluded that with phenolphthatein as the indicator phosphoric acid reacts as a dibasic acid and boric acid in the presence of mannitol as a monobasic acid.

Kolthoff (5) reported the determination of boric acid in the presence of phosphoric acid with phenolphthalein as the indicator. Mannitol was used in the estimation of boric acid. The end point for the titration is at a pH of 8.7.

Vastagh (6) claims no interference results in solutions which have been previously neutralized by potassium hydroxide with methyl red as the indicator when these methods are used except from the presence of silicic acid.

The reliability of the titration methods has been further tested by Foote (7) in his "Determination of Boron in Waters." He concludes that the titration method is the most convenient and reliable of all those studied.

TABLE I

Titration Results of Known Amounts of Boric Acid in Urine
(100 c. c.)

Subject	Amount NaOH Used c. c. N/10	Amount H_3BO_3 Added mg.	Amount H_3BO_3 Found by Titration mg.	Amount H_3BO_3 Found, Per Cent of Total
A	38.78	266.7	239.9	89.9
B	39.43	271.5	243.9	89.8
C	36.98	254.3	228.8	89.8
D	39.50	271.5	244.4	90.0
E	36.15	268.5	223.7	83.3
F	38.00	270.1	235.0	87.0

EXPERIMENTAL

Twenty-four hour samples of urine were collected from six subjects. One hundred cubic centimeter volumes were run from the well-shaken 24 hour collections. No effort was made to control the diet of the subjects—they did not board at the same place—except that each subject ate approximately a uniform diet during the period of the study.

The 100 cc. urine sample was made distinctly acid to methyl red with hydrochloric acid, boiled gently for five minutes, to remove carbon dioxide, cooled and phenol red added. It was then adjusted to a pH of 7.6 by addition of carbon dioxide free sodium hydroxide and approximately 0.1 N hydrochloric acid if necessary. Three grams of mannitol were then added and the titration to a pH of 7.6 repeated. The amount of standard alkali needed for this adjustment in pH is a measure of the quantity of boric acid present. The equivalence of the standard alkali in boric acid was obtained by titration of known strengths of boric acid solutions.

Urine from each of the subjects without the addition of boric acid was titrated as blanks to test the procedure and to determine if it was free from borates. Negative results for borates were obtained in all cases.

Because of the color of the urine samples and the resultant difficulty of determining the end point, it was found necessary to decolorize the urine by means of absorbent charcoal. Tests proved that no measurable loss of boric acid resulted from such decolorization. When these facts were established samples of urine with the addition of known amounts of boric acid were titrated. The results for these tests are given in Table I.

TABLE II

ELIMINATION OF BORIC ACID THROUGH THE URINE

Subject	N/10 NaOH per 100 cc. Urine cc.	Volume Urine Voided cc.	Amount H_3BO_3 Found mg.	Corrected Amount H_3BO_3 mg.	Amount H_3BO_3 Adm. mg.	Amount H_3BO_3 Eliminated First Day. Per Cent of that Administered in Day Determined	Amount H_3BO_3 Eliminated in Two Days. Per Cent of Total Administered
1st day							
A	7.20	1627	724	805	975	82.56	
B	7.97	913	728	810	975	83.08	
C	7.65	760	360	400	975	41.99	
D	6.64	1055	433	481	975	49.33	
E	4.76	1182	348	418	975	42.87	
F	7.09	1477	647	744	975	76.31	
2nd Day						2nd Day	
A	10.25	1150	729	811	975	83.18	82.87
B	8.19	892	452	503	975	51.59	67.33
C	10.76	851	566	630	975	64.65	53.32
D	4.99	1673	516	573	975	58.87	54.10
E	7.98	1093	539	620	975	63.60	53.23
F	6.75	1652	689	792	975	81.23	78.77
3rd Day						3rd Day	Three Days
A	9.31	1715	986	1072	975	109.95	91.89
B	7.29	883	398	442	975	45.41	60.03
C	7.24	1492	668	744	975	76.32	60.65
D	4.55	1620	456	507	975	52.03	53.41
E	4.31	1744	465	527	975	54.06	53.51
F	6.57	1456	957	1100	975	112.82	90.12
4th Day							Four Days
A	3.83	877	208	231	000		100.00
B	3.88	1203	444	495	000		76.92
C	3.72	922	212	236	000		68.72
D	3.35	1090	226	251	000		61.95
E	1.22	1680	127	153	000		59.42
F	2.70	1819	300	349	000		102.05
5th Day							Five Days
A	1.10	1217	83	92	000		102.83
B	0.96	776	46	51	000		78.67
C	1.27	819	64	71	000		71.14
D	0.97	1051	63	70	000		64.34
E	1.10	1100	75	89	000		61.78
F	0.90	1200	66	76	000		104.65

The amount of boric acid actually determined is less than theory. During the course of the experiment, determinations were made on known addition amounts of boric acid to the samples with results that checked the results that are recorded in Table I for the different subjects

under observation. The shortage in amounts determined must be due to the presence of particular buffers or the amounts of buffering materials in the different samples. Phosphates do not appear to be the cause of the difference in behavior as E was low in phosphates, while F was average and other investigators (4) (5) have already stated that phosphates do not interfere with the titration of borates. This individual peculiarity will be investigated further.

Corrections are applied in Table II in all determinations to correct for this divergence from theoretical results.

Blanks were run on a 24 hour sample of each subject before boric acid was administered. Then a total of 975 mg. of boric acid in three equal doses were administered daily at two-hour intervals after the three meals respectively, and 24 hours samples of urine collected (from 7:00 A. M. to 7:00 A. M.). One hundred cubic centimeter samples were taken from the well mixed 24 hour collection and titrated as already described for the blanks. The administration of boric acid was continued for three days and the collection of samples and determination of boric acid for six days, when no boric acid was found.

Tests for boric acid on the sixth and seventh days revealed only traces present that were of no quantitative significance.

The data in Table II indicate that the urinary elimination of boric acid is not uniform but varies with the individual and that one hundred per cent may be eliminated through the urine. This is not in harmony with the reported findings of Wiley (8) who states, that 80 per cent is eliminated through the urine and 3 per cent in the feces and perspiration.

SUMMARY AND CONCLUSIONS

1. Buffers in urine affect the quantitative determination of boric acid and corrections must be applied when the titration method is employed.
2. Quantitative elimination of boric acid through the medium of the urine varies in speed and completeness with the individual.
3. Two of the six cases investigated eliminated 100 per cent of the boric acid administered via the urine.
4. There is a considerable lag in the elimination.

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THE ANATOMY OF THE DIGESTIVE SYSTEM OF ONCOPELTUS FASCIATUS DALL. (HETEROPTERA: LYGAEIDAE)

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INTRODUCTION

Oncopeltus fasciatus Dallas occurs over a wide range extending from Massachusetts westward over the greater part of the United States east of the Rocky Mountains and south and westward to Florida, Texas, California, Mexico and Brazil.

Its principal host plant is the common milkweed *Asclepias syriaca* L. but late in the summer the insect may be observed on willow foliage and the flowers of golden-rod and other Compositae.

This study was initiated in a course in entomology at the Ohio State University given by Dr. C. H. Kennedy on "The Morphology and Development of Insects." The interest developed in this course led to further pursuance of the work as a thesis problem.

The insects studied were collected from foliage of the common milkweed growing in Vigo County, Indiana.

The writer wishes to express his sincere appreciation for the helpful criticisms and assistance given by Dr. Kennedy and also for the worthy suggestions of fellow students.

METHODS

The collected material was killed and immediately placed in Kahle's fluid where it remained for two hours. After washing the material was stored in seventy per cent alcohol. For much of the gross anatomy study live material was dissected under a normal saline solution. Mayer's Hemalum and Fast Green FCF were employed in staining histological structures.

GROSS ANATOMY OF THE DIGESTIVE TRACT

GENERAL ANATOMY

Upon the basis of embryological origin the digestive tract is divided into three major portions. The stomodaeum or fore-gut arises as an ectodermal invagination at the cephalic region of the embryo. In like

manner the proctodaeum or hind-gut arises at the caudal end. Since these two divisions of the tract are infolded portions of the body wall their own walls have the same essential structure as that of the body integument. The mesenteron or mid-gut is the connective portion of the tract between the stomodaeum and proctodaeum. Its epithelium is from embryonic endodermal tissue.

The three general divisions of the digestive tract are further differentiated into the following parts:

I Stomodaeum
- Pharynx
- Oesophagus
- Oesophageal valve

II Mesenteron
- First stomach
- Second stomach
- Third stomach
- Fourth stomach

III Proctodaeum
- Pylorus (?)
- Malpighian tubules
- Rectum
- Anus

In keeping with the phytophagous habits of the insect the entire digestive tract is of medium length being approximately one and one-half times the length of the body. It is relatively straight except in the regions of the second and third stomachs where it is coiled upon itself.

THE STOMODAEUM

The pharynx is a slightly enlarged portion of the stomodaeum just posterior to the mouth cavity and in the anterior half of the head cavity. It is a connecting portion between the mouth cavity and the oesophagus.

The oesophagus comprises the greater part of the stomodaeum and is approximately one-thirteenth the length of the whole tract. It is very narrow, tubular and extends dorsally from the pharynx along the median axis of the body. Its anterior half is enclosed by the head capsule while its posterior portion extends into the anterior part of the thoracic cavity joining the enlarged first stomach near the anterior edge of the scutellum. At the junction of the oesophagus and first stomach is located the oesophageal or stomodaeal valve.

THE MESENTERON

Just posterior to the oesophageal valve is the greatly enlarged first stomach. Its size and shape vary much depending upon the quantity of food material present within it but it usually extends well into the abdominal cavity along the median axis of the body. It is approximately one-third the length of the entire tract and is the region of the greatest diameter. Its walls at the anterior end usually lie in circular

folds while it enlarges in pear-shaped fashion posteriorly into a smooth-walled structure. In the thoracic cavity it is completely enclosed by thick bunches of wing and leg muscles.

THE SALIVARY GLANDS

The salivary or labial glands lie dorsally and closely to the anterior end of the first stomach in the thoracic cavity and extend anteriorly covering the posterior portion of the oesophagus. They are paired, one gland lying on either side of a median line through the walls of the oesophagus and first stomach. Each gland consists of four parts. Two parts are each single pyriform lobes. One part is bi-lobed. The other part is a convoluted tube the distal end of which lies within the head cavity.

Each gland has a straight-walled duct through which the gland empties into the mouth. This duct arises at the junction of the lobes of the gland; it has an open lumen. This exit duct and its mate from the other gland join at the base of the beak into a very short common salivary duct which empties into the hypopharynx. This region of the salivary pump was not investigated closely.

Plate I, Fig. 1 illustrates the right salivary gland slightly pulled away from the wall of the first stomach to show the distinct parts. The left gland is turned ventral side up to show the junction of the salivary duct and the gland.

According to Snodgrass these glands are of ectodermal derivation arising in the embryo as paired invaginations just behind the bases of the rudiments of the second maxillary appendages. They are therefore treated here in connection with the stomodaeum.

At its posterior extremity the first stomach gradually narrows into a convoluted tube called the second stomach. The walls of the second stomach lie in folds the entire length of that organ and are of a pale yellow coloration in living specimens. The diameter of the second stomach is usually about 0.5 millimeters although this may fluctuate somewhat largely due to the amount of food material contained therein. It is slightly longer than the first stomach being a little less than one-third the length of the whole tract. The second stomach is usually coiled within the middle third of the abdominal cavity, however, it may be found in the posterior third in those cases in which the first stomach is unusually enlarged with food material.

Figure 1 illustrates the second and third stomachs pulled out of their normally coiled position.

The third stomach is scarcely distinguishable from the second stomach when the third stomach is void of food material except for the lack of folds in its walls. When filled with food, however, it is usually oval to spherical in shape and of a dark brownish coloration. It is from two and one-half to three millimeters in length. The third stomach narrows down into a short, narrow, smooth-walled tube called the fourth stomach.

The fourth stomach is about one millimeter in length and terminates the mesenteron posteriorly, unless the next enlargement of the canal into which the Malpighian tubules enter may be of endodermal origin.

THE PYLORUS (?)

Connecting the fourth stomach to the rectum is a slightly flattened, bulbular, smooth-walled enlargement of the tract questionably called the "pylorus." It is approximately one millimeter in length. Its diameter is nearly twice its length. Histological study gives evidence that this region may be either part of the mesenteron or perhaps part of the proctodaeum. This evidence will be discussed in connection with the histology of the digestive tract.

THE PROCTODAEUM

As mentioned in the preceding paragraph the "pylorus" may be considered as the most anterior portion of the proctodaeum.

The Malpighian tubules are long and narrow blind tubes extensively coiled throughout the posterior half of the abdominal cavity lying particularly near the dorsal body wall. Their distal ends lie freely in the body cavity and their proximal ends join the "pylorus." They are four in number two of which independently enter each of the lateral walls of the "pylorus." Figure 1 illustrates these tubules as being broken a short distance from their origin. The Malpighian tubules are generally considered to be of ectodermal derivation.

Lying along the median axis of the body, posterior to and connected with the "pylorus," is a thin-walled, pyriform structure called the rectum. Its anterior end is enlarged being about one millimeter in diameter and two millimeters in length. Its walls taper posteriorly into a narrow tube which terminates at the anus.

HISTOLOGY OF THE DIGESTIVE TRACT

THE STOMODAEUM

The stomodaeum anterior to the posterior edge of the head capsule was not studied histologically.

The histological structure of the oesophagus is quite uniform except at its posterior end in the region of the oesophageal valve. A section through the oesophageal walls (Plate II, Fig. 2) discloses the following structures from within outward: (1) intima, (2) epithelial cells, (3) circular muscles and (4) longitudinal muscles.

An inner lining of non-cellular cuticula or intima lies apart from the epithelial cells and separates them from the lumen. The epithelial cell layer is very irregular in shape. It appears mostly as a homogeneous mass except for the scattered nuclei within it. No cell walls are noticeable. Both circular and longitudinal muscles are scattered and are from two to three strands in thickness.

At the junction of the oesophagus and first stomach is the oesophageal valve (Plate II, Fig. 4). The epithelial cells of the oseophagus are elongated forming a fold which extends partially into the lumen of the first stomach. There is a heavy grouping of circular muscles proximal to the basement membrane of the epithelial cells constituting the fold. It is particularly noted that there is no reversal in the relative position of the muscle layers at the oesophageal valve. The intima which lines the

oesphagus ends abruptly just posterior to the fold of cells which make up the valve indicating the posterior termination of the stomodaeum.

THE MESENTERON

Histologically the structure of the mesenteron is much the same throughout. It consists of a layer of epithelial cells resting upon a basement membrane, a layer of internal circular muscles and a layer of external longitudinal muscles. No peritrophic membrane is present which is considered quite typical of sap feeding insects. Likewise an intima is lacking. The epithelial cells throughout the mesenteron, unlike those in the oesophagus, are much larger and show distinct cell walls. A thinness of the muscular layers is characteristic of the mesenteron.

The wall of the first stomach is relatively thin in comparison with the diameter of the stomach. The epithelial cells are short but vary somewhat in shape from nearly cuboidal to oblong. Plate III, Figure 6 illustrates the cellular appearance of the first stomach when it is void of food material. The layer of circular muscles is particularly thin and consists of a single strand. The longitudinal muscles are few and very scattered.

In the second stomach (Plate III, Fig. 8) the epithelial cells are longer and more uniform in length. The circular muscle layer consists of one strand and a partial second strand. The longitudinal muscles, as in the first stomach, are few and scattered.

The histological structure of the third and fourth stomachs (Plate III, Figures 9 and 7) is particularly similar. The epithelial cells vary greatly in size, some cells being six times larger than other cells, thus making the epithelium very irregular in thickness. Activity of the digestive epithelium is noted particularly in the third stomach. Some of the distended epithelial cells in the third stomach are seen undergoing a degeneration process. Also, a regenerative cell is shown. In the degeneration process, according to Snodgrass, the mesal border of the degenerating cell swells out in the form of a bud, which becomes constricted at its base and finally separates as a free sphere from the body of the cell as illustrated on Plate III, Figure 9. These disintegrated cells are replaced with new cells formed from the regenerative cells. In the fourth stomach some of the epithelial cells show striated borders. The muscularis in the third and fourth stomachs is heavier than in any other portion of the mesenteron. A layer of two strands of circular muscles is present. No longitudinal muscles were detected in the third stomach. A few scattered longitudinals are noticeable in the fourth stomach.

THE PYLORUS (?)

This enlargement of the digestive tract, into which the Malpighian tubules empty, is made up of long, very thin epithelial cells resting upon a basement membrane. Lying closely to and outside of the basement membrane is a layer of rather heavy, plainly striated, longitudinal muscles from one to two strands in thickness. No circular muscles were detected. No pyloric valve was found. Because only longitudinal muscles are present there is no reversal of the muscular layers in the "pyloric" region.

The point of attachment of the Malpighian tubules commonly marks the anterior extremity of the proctodaeum. Embryologists also generally agree that these tubes take their origin as outgrowths of the proctodaeum. The fact that the Malpighian tubules enter the "pylorus" would indicate that this region is part of the proctodaeum. The proctodaeum, however, is characterized by having an intima. Contrary to this, the so-called "pylorus" has no cuticular lining. This condition, then, would indicate that the "pylorus" is a continuation of the mesenteron.

Snodgrass defines the pylorus as "an anterior part of the proctodaeum usually containing the pyloric valve, sometimes distinctly differentiated from the true intestinal region and forming anatomically the rear end of the stomach."

Our evidence, then, is not decisive as to whether the lining epithelium is derived from endoderm or from proctodaeal ectoderm.

THE PROCTODAEUM

The Malpighian tubules join directly into the walls of the "pylorus." The structure of these tubes is relatively simple. The lumen of the tube in cross section is enclosed by three or four large, thin-walled cells which contain very large and distinct nuclei. No muscularis could be detected.

The structure of the rectum is quite similar to that of the oesophagus. From its lumen outward it is made up of the following structures: (1) intima, (2) epithelial cells, (3) internal circular muscles and (4) external longitudinal muscles. The intima which separates the epithelium from the lumen lies more closely associated with the epithelial cells than it did in the oesophagus. The epithelial cells are similar to those in the oesophagus in that they show scattered nuclei and no cell walls. They are also very irregular in shape. The circular muscle layer consists of a single strand of muscles. The longitudinal muscles are rather heavy. They occur in scattered patches of from one to two strands in thickness.

Investigation of an anal sphincter could not be carried on satisfactorily due to the chitinized walls about the anal opening.

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EXPLANATION OF PLATES

Plate I

Fig. 1. Gross dissection; alimentary tract removed in part from the body cavity. Left salivary gland turned ventral side up. Malpighian tubules cut off near their point of origin.

Plate II

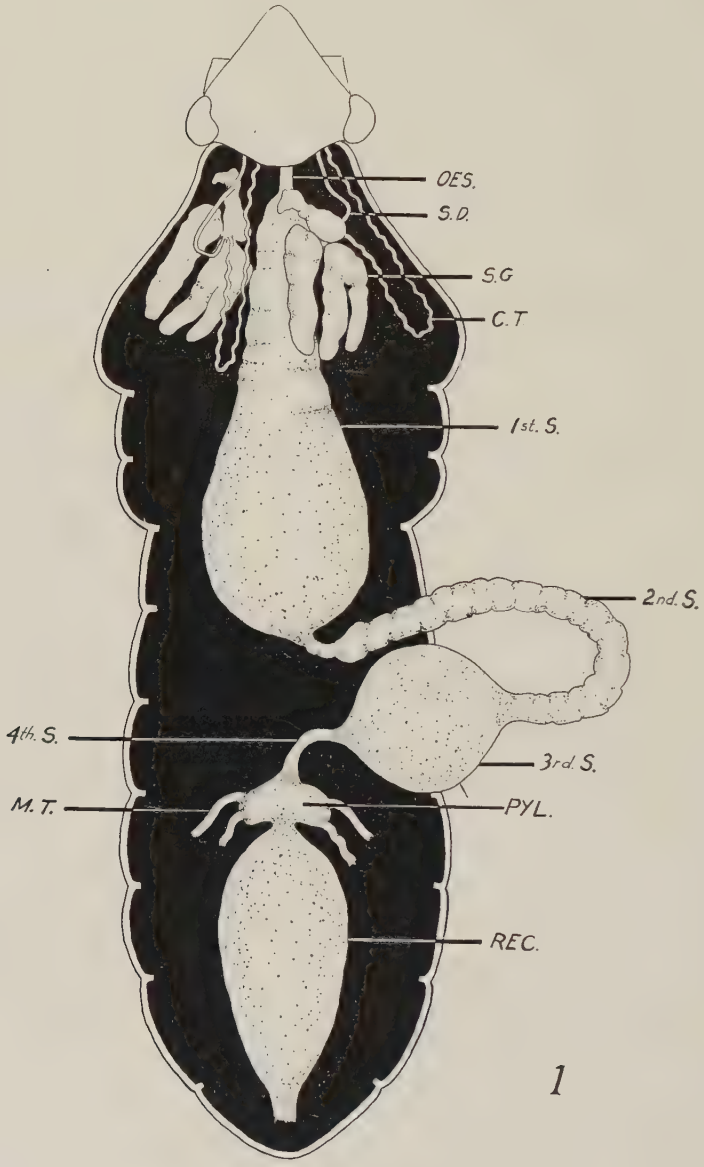
Fig. 2. Cross-section through the oesophagus.
Fig. 3. Longitudinal section through the "pylorus."
Fig. 4. Longitudinal section through a portion of the oesophagus, the oesophageal valve and part of the first stomach.
Fig. 5. Cross-section through a Malpighian tubule.

Plate III

Fig. 6. Cross-section through the first stomach.
Fig. 7. Cross-section through the fourth stomach.
Fig. 8. Cross-section through the second stomach.
Fig. 9. Cross-section through the third stomach.

KEY TO ABBREVIATIONS

C.M.—Circular muscle.
C.T.—Convoluted tube.
EPI.—Epithelial cell.
INT.—Intima.
L.M.—Longitudinal muscle.
LU.—Lumen.
M.T.—Malpighian tubule.
OES.—Oesophagus.
O.V.—Oesophageal valve.
PYL. (?)—"Pylorus."
REC.—Rectum.
R.C.—Regenerative cell.
1st. S.—First stomach.
2nd. S.—Second stomach.
3rd. S.—Third stomach.
4th. S.—Fourth stomach.
S.B.—Striated border.
S.C.—Secreting cell.
S.D.—Salivary duct.
S.G.—Salivary gland.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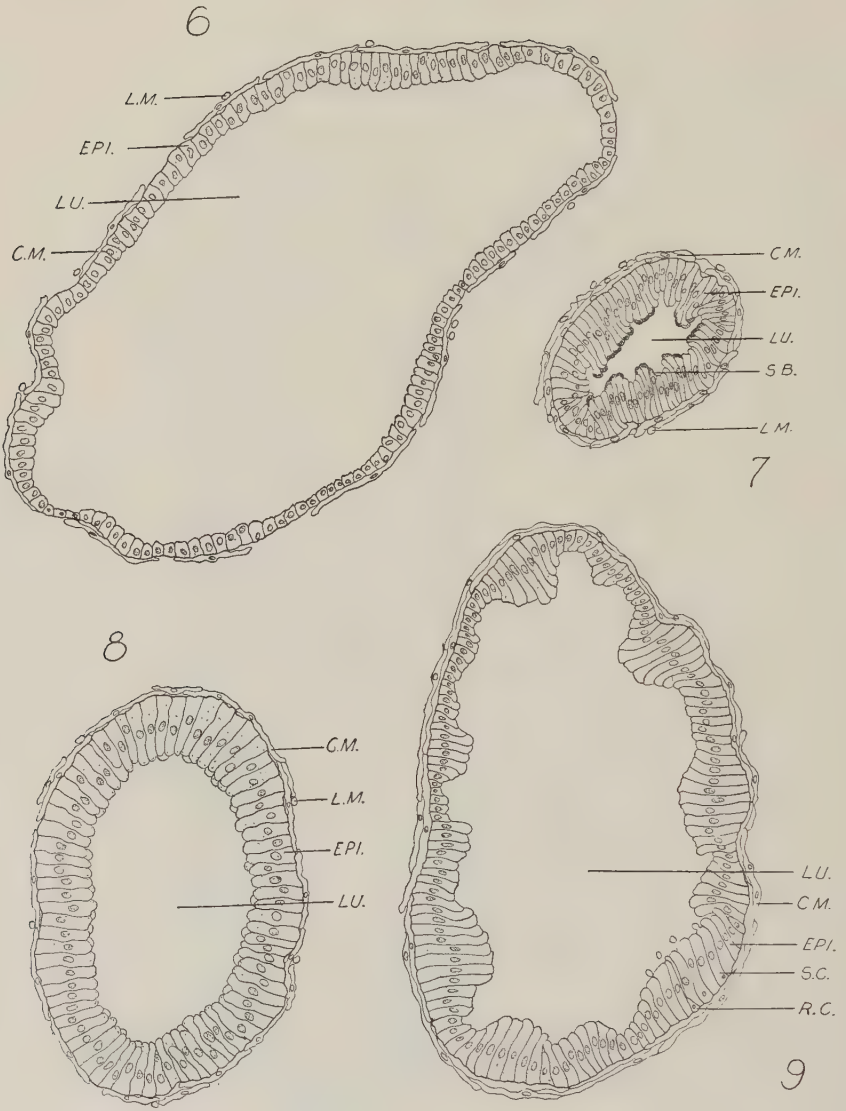
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SOME NEW SPECIES OF IDIOCERUS (HOMOPTERA–CICADELLIDAE)

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Idiocerus borealis n. sp.

Resembling *pallidus* in form and appearance but with simple antennae and smaller in size. Length 5.5–6 mm.

Vertex almost parallel margined, male antennae without discs or black coloration.

Color pale yellow without dark markings, black markings of abdominal segments visible through elytra.

Genitalia: Female segment rather strongly produced to form a blunt median tooth. Male plates rather broad.

Described from one female specimen from Amery, Wisconsin, and two male specimens from Pembine, Wisconsin and Cameron, Wisconsin, respectively collected during July and August, 1916. Holotype male (Pembine, Wisconsin) allotype female and male paratype in senior author's collection.

Idiocerus levis n. sp.

Resembling *pallidus* in form and appearance but with slight discal enlargements on antennae. Length 5.5–6.5 mm.

Male antennal discs only slightly larger than antennae and elongate.

Color pale yellow, elytra appearing milky white.

Genitalia: Female segment rather strongly roundedly produced at middle. Male plates rather long and narrow.

Described from a pair of specimens collected at Meddybemps, Maine, July 13, 1922, by R. J. Sim. Holotype male and allotype female in senior author's collection.

Idiocerus solus n. sp.

Resembling *nervatus* but with faint markings and without discs on antennae. Length 4.5–5 mm.

Vertex shorter at middle than next eyes, broadly curved. Antennae of male simple, without discs.

Color green tinged with yellow. Face vertex and pronotum unmarked. Scutellum with faint markings in basal angles. Elytra subhyaline, veins pale, inconspicuous.

Genitalia: Female segment almost truncate, slightly produced at middle. Male plates rather short and broad.

Described from a pair of specimens collected at Greensburg, Pennsylvania, August 21, 1901, and a pair collected at Clarksville, Tennessee, July 3, 1915. Holotype male, allotype female (Greensburg, Pa.) and male and female paratypes in collection of senior author.

Idiocerus pyramidatus n. sp.

Resembling *nervatus* but larger, darker green without dark markings. Length 5–5.5 mm.

Vertex shorter at middle than next the eyes. Antennal discs of male rather large, black, elongate oval, apex tapered.

Color green, basal angles of scutellum yellow, elytra subhyaline. Nervures pale, indistinct.

Genitalia: Female segment short, roundedly produced, forming a broad blunt tooth at middle. Male plates narrow.

Described from three male and three female specimens collected at Prescott, Huachuca Mts. and Chiricahua Mts., Arizona and Davis Mts., Texas, during June and July, 1935, by Prof. J. N. Knull. Holotype male (Huachuca Mts., Ariz.), allotype female (Chiricahua Mts.), and male and female paratypes in collection of senior author.

Idiocerus stellaris n. sp.

Resembling *suturalis* but distinctly marked and with elongated male antennal discs. Length 6–7 mm.

Male antennal discs elongate oval, pointed at both ends.

Color yellow, face and vertex unmarked. Pronotum brown except for anterior margin and curved spot along margin behind each eye. Scutellum yellow, basal angles brown elytra uniform smoky brown except for anterior costal margin, veins dark. Beneath yellow.

Genitalia: Female last ventral segment roundedly produced. Male plates long and narrow.

Described from one female and nine male specimens from Northeast, Pennsylvania, July 4 to 12, 1928; Greenfield, Pennsylvania, July 20, 1920; Cranberry Lake, New York, July, 1917, and July and August, 1924; and Tobyhanna, Pennsylvania, August 14, 1920 (J. G. Sanders). Holotype male (Cranberry Lake, N. Y.) allotype female (Tobyhanna, Pa.) and male paratypes in the senior author's collection.

Idiocerus verticis (Say)

Jassus verticis Say Jour. Acad. Nat. Sci. Phila., 6 : 308 (1831); Compl. Writ., II, 383.

The name *verticis* has been applied for many years to a small insect with two round black spots on the vertex. According to the original description the vertex, pronotum, and scutellum are irrorate but without black spots on the vertex. As a consequence a neotype male which agrees with the original description is erected at this time, collected at Covington, Tennessee, June 18, 1915, by the senior author and in his collection. The type locality was cited as Missouri by Say.

Idiocerus rotundens n. sp.

Resembling *verticis* in size and appearance but paler with two small round black spots on vertex. Length 4.5–5 mm.

Vertex shorter at middle than next the eyes, antennae with large, circular terminal black discs.

Color pale yellow, ocelli black, face with a broad longitudinal orange stripe. Clypeus, sutures of face and lorae orange. Vertex with a round, median dusky area and a round black spot either side. Pronotum pale, dark spots of scutellum visible. Scutellum pale, marked only by the black spots at base. Elytra white, veins to apical cross veins white, beyond apical cross veins, brownish. Abdomen and beneath pale, yellowish, without dark markings.

Genitalia: Female last ventral segment truncate. Male plates long and slender.

Described from a female and two male specimens collected at Beloit, Wisconsin, July 11, 1936, and a male from Milwaukee, Wisconsin, July 18, 1916, all collected by the senior author. Holotype male (Milwaukee, Wis.), allotype female, and male paratypes in senior author's collection.

Idiocerus tenuens n. sp.

Resembling *verticis* in size and general appearance, but darker and with apical portions of antennae enlarged. Length 5 mm.

Vertex almost parallel margined. Male antennae with apical third slightly widened and black forming an elongate, narrow disc widened toward apex and narrowed basally.

Color yellow, face with a slightly darker median stripe. Pronotum with a spot either side of, and anterior to middle. Basal angles of scutellum with black triangular spots which are visible through pronotum. Elytra subhyaline with dark veins.

Genitalia: Male plates narrow.

Described from a single male specimen collected at Austin, Nevada, August 3, 1936, by J. N. Knull. Holotype male in senior author's collection.

Idiocerus nigrens n. sp.

Resembling *musteus* in form and color but more darkly marked and with small round antennal discs. Length 4.5 mm.

Male antennae with small oval terminal discs.

Color, yellow, vertex with a pair of medium sized round black spots and an oblique mark behind each next the eyes. Pronotum black, humeral angles narrowly white margined. Scutellum black, a pale spot on margin midway on either side and a small spot at apex white. Elytra milky white, basal third of inner clavus and apical third black. Apex of elytra smoky. This gives the appearance of a dorsal black stripe interrupted twice. Male plates short and very narrow.

Described from a single male specimen from Newport, Washington, August 8, 1926, collected by R. W. Haegele.

Holotype male in collection of senior author.

Idiocerus cinctus n. sp.

Resembling *formosus* but smaller, paler in color with two conspicuous transverse bands and with simple antennae in the male. Length 5 mm.

Vertex almost transverse, longer next the eyes than length at middle. Male antennae simple, without discs.

Color yellow, face and vertex unmarked. Pronotum milky white, anterior half mottled with brown. Scutellum with basal angles and a pair of large round spots on the disc, brown. Elytra milky white, transparent. A broad transverse band across apical third of clavus, the apex of elytra to base of apical cells and the anterior costal area, dark brown. Anterior half of outer claval vein brown, apical half white.

Genitalia: Male plates rather broad and long.

Described from two male specimens collected at Idaho City, Idaho, July 13, 1930 (DeLong), and one male from La Grande, Oregon, collected by Dr. H. H. Ross, July 30, 1936. Male holotype and male paratype in senior author's collection. Male paratype in Illinois Natural History Survey collection.

Idiocerus chisosus n. sp.

Resembling *dolosus* in general appearance but paler in color. Length 4.5–5 mm.

Vertex almost transverse and parallel margined. Male antennae with small elongate oval discs.

Color pale brown, face unmarked, a pair of large round black spots on vertex. Pronotum with a row of irregular black spots on anterior margin either side of middle. A pair of black triangular basal spots and a pair of small round spots on the disc of scutellum. Elytra smoky brown, veins white.

Genitalia: Female segment roundedly produced, shallowly notched at middle. Male plates narrow.

Described from a series of eight female and fourteen males collected at Davis Mts. and Chisos Mts., Texas, and Chiricahua Mts., Arizona, during July, 1936, by J. N. Knull. Holotype male (Davis Mts., Arizona) allotype female and male and female paratypes in the senior author's collection.

Idiocerus caliginosus n. sp.

Resembling *dolsus* in form and general appearance but smaller and with darker markings. Length 5 mm.

Vertex transverse, shorter at middle than next either eye.

Color white marked with black and brown. Face heavily mottled with black. Sutures of front and clypeus with faint black marginal lines. Vertex with the two round black spots fused with angular spots which extend to upper margins of eyes. A pair of proximal spots between them. Pronotum heavily mottled on each side of pronotum excepting a broad longitudinal milky white stripe in the middle. Scutellum with basal angles, a pair of proximal spots at base, a pair of triangular spots on disc and a pair of triangular spots at apex black. Elytra smoky, veins broadly white interrupted with black on clavus and disc of corium. Outer veins white, apical veins brown.

Genitalia: Female last ventral segment strongly roundedly produced, slightly notched at center.

Described from two female specimens collected in the Chisos Mts., Texas, July 9, 1936, by J. N. Knull. Holotype female and paratype female in senior author's collection.

SOME EFFECTS OF TEMPERATURE ON THE DEVELOPMENT AND OVIPOSITION OF MICROBRACON HEBETOR (SAY)

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The present paper summarizes some preliminary observations on the life history of *Microbracon hebetor* (Braconidae) as a parasite of the Mediterranean flour moth, *Ephestia kühniella* Zeller, under controlled temperature and humidity conditions. This work was done at the Ohio State University in 1931 and the writer is deeply indebted to Professors Alvah Peterson and William M. Barrows for advisory assistance during the progress of the study.

METHODS

The cages used for rearing *M. hebetor* were 18 x 50 mm. shell vials which were closed with screen caps. A fresh, moist, seedless raisin, mounted on an insect pin, was kept in each container as a possible source of moisture and food as a supplement to the normal feeding from punctures made in the host larvae.

Temperature variations were held within about one degree Centigrade on either side of the desired temperature and relative humidity was maintained near 73.0 per cent by means of saturated solutions of sodium chloride.

Examinations of the insects were made daily at about the same hour and two well developed larvae of *E. kühniella* were supplied as hosts to each female parasite. The females were confined singly in cages and were transferred daily to clean vials by means of a suction tube. Fertile females which were reared at 26° and 28° C. were used in the oviposition studies. Males were excluded during the tests to avoid disturbing the oviposition reactions. The eggs, which are deposited externally on the host larvae, were counted by rotating the vial under a binocular microscope.

RESULTS

Pre-imaginal development. The duration of the developmental stadia with standard errors is shown in Table I and is illustrated by Figure 1. The time required by individual insects

varied from 8 days at 32° to 39 days at 16° C. The egg and larval stages combined required less than one-half of the time spent within the cocoon or about thirty per cent of the time required from deposition of the eggs to the emergence of the adults. Determinations were made of the duration of the egg and larval periods in combination since the brevity of the stadia made it difficult to determine the values separately.

Between 20° and 32°, the rate of development appears to have a linear correlation with temperature although the regression line may be slightly curvilinear (Fig. 1). These results are, therefore, not strictly in accordance with those of Payne (1934) who states that the curve is probably exponential. However,

TABLE I

Development of *M. hebetor* at Different Constant Temperatures (Duration of the Developmental Stadia in Days)

Temperature ° C.	Egg and Larval Period	Number Reared	Pupal Period	Number Reared	Total Pre-imaginal Period	Number Reared	Index Rate of Development	Thermal Increment (above 12.7) in Day-Degrees
32	2.40	27	5.72	28	8.12 ± .06	28	12.31	156.72
30	2.62	175	6.21	279	8.83 ± .04	279	11.32	152.76
28	3.03	245	6.86	149	9.89 ± .06	149	10.11	151.32
26	3.48	160	8.07	233	11.55 ± .06	233	8.66	153.62
24	4.11	96	9.76	164	13.87 ± .10	164	7.21	156.73
20	6.86	123	14.35	97	21.21 ± .12	97	4.71	154.83
16	10.73	110	21.98	41	32.71 ± .28	41	3.06	107.94

the present study indicates that the curve may be more definitely exponential below 20° since a marked deviation occurs at 16° and a few specimens were reared at 12° which is below the minimum effective temperature shown by the linear relationship. The rate of development used in Table I and Figure 1 is an index which is equal to 100/time, or the per cent of total development which would take place in one day at the mean rate for the entire period. The regression line (Fig. 1) was calculated by the least squares method.

As is shown in the last column of Table I, the thermal increment necessary for the development of *M. hebetor* approaches a constant value for the temperature range between 20° and 32°. Effective temperatures, as are shown in Table I (last column) are those above 12.7° as indicated by the calculated regression line (Fig. 1) and the value of the thermal constant is 154 day-degrees.

As has been recorded previously, (Whiting 1921 and Schlöttke 1926) the coloration of the adults varied progressively from light to dark as the temperature at which they were reared graded downward.

Oviposition. An indication of the fecundity of *M. hebetor* is afforded by a maximum deposition of 312 eggs by one individual while the mode for 53 individuals which were reared at 26° and 28° C. falls between 100 and 200 eggs.

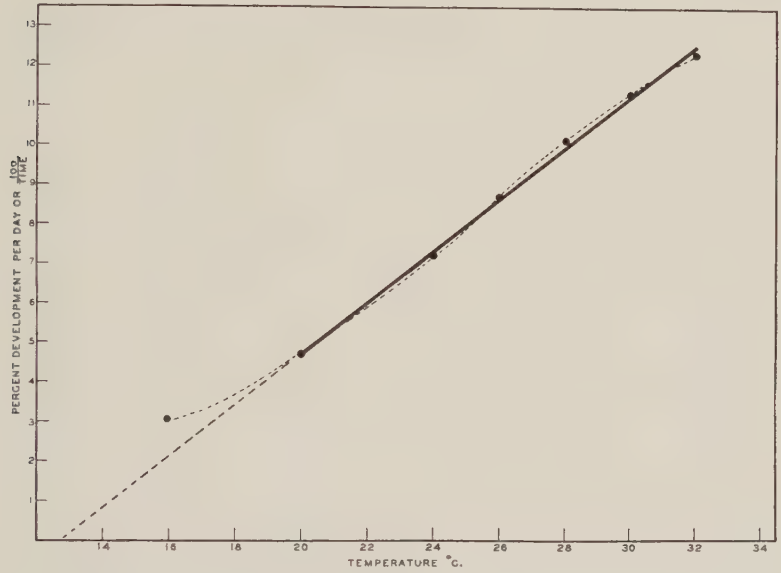

FIG. 1. Graph showing rates of development at different constant temperatures.

The minimum temperature at which eggs were regularly deposited was 14° C. With few exceptions, egg deposition ceased abruptly when laying individuals were transferred to a cabinet which was controlled at 12° C. The maximum temperature at which eggs were regularly obtained was 36° C. Egg-laying was suspended at 38° C. except in the case of exceptional individuals which deposited several eggs under these conditions. The optimum temperature is near 26° C. since the rate of egg-laying is near a maximum at this temperature and the total number of eggs deposited is greater than at higher temperatures where the oviposition period is shorter. The pre-oviposition period is very short since eggs were usually obtained on the first or second day

following emergence. A post-oviposition period was not very evident since only a few individuals showed a definite lapse in egg-laying before death occurred. Fertility apparently does not have a marked effect on egg-laying since virgin females exhibit a strong and uniform oviposition behavior. The eggs of virgin females develop but always produce males.

An influence of temperature on the oviposition rate and fecundity of insects has been observed by a number of authors. Hunter and Pierce (1912) observed that the oviposition rate of the cotton boll weevil, *Anthonomus grandis* Boh., was strongly affected by temperature. No data are given but the influence of

TABLE II

Rates of Egg-Laying of *M. hebetor* at Different Constant Temperatures

Temperature –C.	Number of Females	Oviposition Rate (Eggs per Day per Female)	Temperature Coefficients (μ)
38	5	0.00	
36	7	12.59	
28	21	14.70	
26	10	14.57	24,200
24	22	11.10	18,000
22	18	9.03	23,900
20	22	6.85	19,200
18	8	5.47	20,400
16	17	4.29	
14	5	1.80	
12	7	0.00	

temperature is illustrated by a curvilinear regression line. Studies of the effect of temperature on the fecundity of *Trichogramma evanescens* Westwood, show that the oviposition rate of this species is largely a function of temperature. (Schulze 1926). The correlation shown by these data was regarded as curvilinear by Janisch (1930), who fitted the data with an exponential regression curve. The effect of a temperature gradient on the rate of egg-laying of the queen bee is very definitely curvilinear as is shown by Dunham's data (1931). The rate of reproduction of the grain aphis, *Toxoptera graminum* Rondani, is also apparently a curvilinear function of temperature (Wadley (1930) and data of Isely (1932) on the cotton boll weevil suggest a similar relationship.

Data on the rate of egg-laying of *M. hebetor* at various constant temperatures are shown in Table II and are illustrated by

Figure 2. These results also show that the effect of temperature on the oviposition rate is not directly proportional to temperature through an appreciable range. The effect of the temperature gradient appears to define a sigmoid curve between 16° and 28° C. which indicates that the oviposition rate may be better interpreted as an exponential than as a linear function of temperature.

The master reaction theory that the velocities of such processes are controlled by the speed of a single chemical reaction has been quite generally considered by physiologists and temperature characteristics (μ of the Arrhenius equation) have been

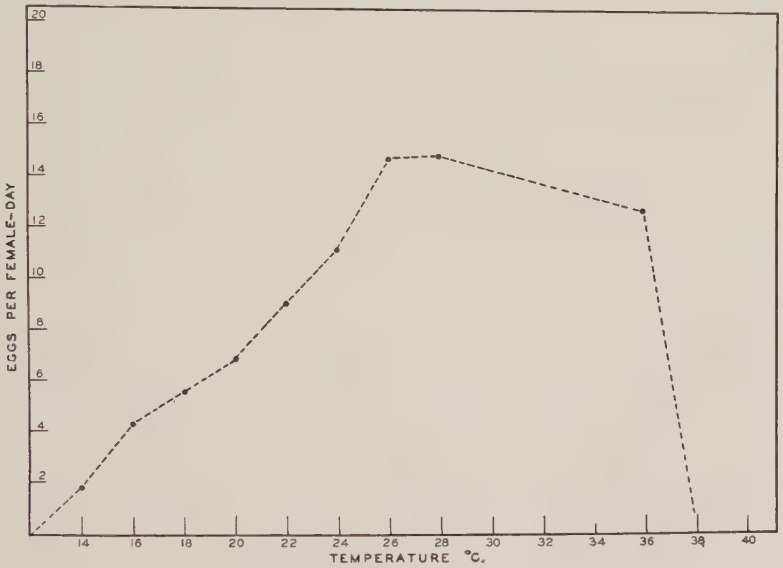

Fig. 2. Graph showing oviposition rates at different constant temperatures.

calculated for a great variety of biological activities. Objections to the use of the Arrhenius formula in biology have been made by Fulmer and Buchanan (1929) and by Belehrádek (1928–30) who advances the theory that the speed of such reactions is dependent upon the viscosity of protoplasm or the "rate of diffusion in viscous media."

Consideration of different regression equations has demonstrated the difficulty of finding the best hypothesis by the method of curve fitting. Variability in the oviposition response as well as the fact that the curve extends only through a narrow

temperature range make it evident that a slight difference in agreement in favor of one equation is not significant. However, it is shown in Table II that the oviposition rates are not obviously discordant with the master reaction theory since the value of the temperature characteristic does not vary regularly in any order which would indicate that it is not a constant for the process between 16° and 26° C. The data depart widely from the calculated regression curve at higher temperatures and also at 14° and below the minimum temperature for oviposition since the curve does not reach a zero.

These results indicate that the effect of temperature on the oviposition rate does not permit the simple analysis which is provided by the thermal constant theory for the development of this species since a definite thermal increment does not have a constant effect through any range of temperature. In the case of such relationships, factorial treatment of thermal increments between narrow temperature limits would provide a closer index to the influence of temperature on insect oviposition than would the method of direct temperature summation by day-degrees.

SUMMARY

The approximate duration of the developmental stages of *M. hebetor* has been determined at constant temperatures for the range of 16° to 32° C. The egg and nymphal periods combined require about one-third and the pupal period about two-thirds of the total pre-imaginal period. The data on development conform well to the thermal constant theory between 20° and 32° C. Mean oviposition rates do not indicate a thermal constant but show a sigmoid relationship which shows only a slight difference in the rate of egg-laying between 28° and 32° C. The thermal constant for development has a value of 154 day-degrees and the temperature characteristic for oviposition between 16° and 26° C. has a least squares value of 21,400.

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THE EMBRYO SAC OF ERAGROSTIS CILIANENSIS (ALL.) LINK

A New Type Embryo Sac and a Summary of Grass Embryo Sac Investigations

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The embryo sacs of the grasses have been examined by about twenty-five investigators. Of the sixty grasses studied only twenty-three species have fairly complete data recorded concerning the development of the embryo sac, and forty-seven species have the type of embryo sac recorded. The number and position of the antipodals, which vary from three to sixty (Bambusa, in tables), have attracted more attention than any other phase of the embryo sac studies, for the antipodals have been studied in fifty-five species. Information about the group as a whole is scattered and incomplete, as will be seen in the accompanying tables, and there is variation in the records.

Eragrostis cilianensis (All.) Link, is the name preferred in Hitchcock (18) for the grass known to many as *Eragrostis major* Host. The spikelets were prepared by killing and fixing in hot crom-acetic or hot F. A. A. and kept in 50% Hydroflouric acid from five to ten days before embedding.

THE SPIKELETS AND OVULES

The spikelets of this grass have from ten to forty flowers with the basal flowers maturing first. Longitudinal sections of the whole spikelet show the flowers in various stages of maturity from the base to the tip. The young ovule develops at right angles to the carpel wall (Fig. 1) and gradually grows so that its longitudinal axis is finally parallel with that of the carpel (Fig. 10). The inner integument develops faster than the outer, which never completely covers the ovule and finally disappears (Figs. 12 and 13).

THE ARCHESPORIAL CELL AND MEGASPORES

There is one archesporial cell and no tapetal cell. Four megaspores are formed and are arranged in the T-form (Figs. 2, 3, 4, 5). The young ovules of Eragrostis are so small that 4-micron sections had to be cut to be certain of the T-form tertad. Schnarf (1926, *Bambusa, Coleanthus*) and Horton and Beck (1932), *Bromus marginatus*) show T-form tetrads; and Miller (1920, *Zea*) reports no walls between the megaspores and says that all four function ("lily type"). Weatherwax reports a linear tetrad in Zea, as is the case in all other species reported.

The inner megaspore (Figs. 3, 4, 5) of Eragrostis always grows into the embryo sac and its nucleus does not divide until after the disintegration of the other three megaspores (Fig. 5). This is the case in all other grasses that have been studied except that Anderson (1927) reports that in *Poa* the outer megaspore develops occasionally and that there are sometimes two rows of megaspores from two archesporial cells.

THE EMBRYO SAC

The embryo sac develops as the normal type through the two- and four-nucleate stages (Figs. 6, 7). With the formation of the eight-nucleate stage the four chalazal nuclei are immediately separated from the rest of the embryo sac as four antipodal cells (Figs. 8, 9, 10); one or two of these divide immediately so that there are commonly five or six antipodal cells (Fig. 11) at fertilization time. The number of antipodals in grass tribes varies from three to sixty, as shown in the tables.

The four nuclei at the micropylar end of the sac function, as the egg, one synergid, and two endosperm nuclei (polar nuclei) (Figs. 10, 11). This organization of an embryo sac is a new type not only for the grasses but for all plants. The number of antipodals in *Eragrostis* is always four or more and they are immediately separated from the rest of the sac as antipodal cells. Consequently no chalazal nucleus takes part in the formation of the endosperm. Only one synergid is ever formed, and the egg and the one synergid are separated from the remaining two nuclei as cells (Figs. 10, 11). These remaining two nuclei fuse in the formation of the endosperm nucleus (Figs. 10, 11). The pollen tube enters through the micropyle and fertilization occurs as usually described.

The embryo sacs of forty-two grasses have been reported as normal-T sacs. Three cases have been found to have the Scilla-T (*Coleanthus*, Schnarf, 1926; *Melica nutans* and *M. altissima*, Fischer, 1880). Miller (1920) found that in *Zea* all four megaspores function in the formation of the eight-nucleate sac as in the so-called "lily type" embryo sac, and Weatherwax (1919) found the normal-T in *Zea*.

DEVELOPMENT OF SEED COATS

The embryo sac elongates and the chalazal end absorbs its way into the nucellus, while the antipodals remain *in situ* and so become lateral to the embryo sac (Figs. 11, 12). Most of the nucellus is absorbed by the developing endosperm until practically only the outer layer remains (Fig. 12), and even that is at last partly destroyed (Fig. 14). The inner integument completely surrounds the ovule and the outer integument disappears; so that the seed coat is made up of the inner integument and one layer of the cells of the body of the ovule except on the side of attachment to the carpel (Figs. 14, 16). With but one exception in all species examined in the grasses the outer integument disappears and the inner integument becomes the seed coat (Figs. 14, 24, 36, et al). Anderson states that in *Poa* the outer integument does not entirely disappear but the cells are much crushed.

THE ENDOSPERM

The endosperm is free-nuclear, and by the time the fertilized egg has divided there are from 25 to 35 nuclei lying in the periphery of the cytoplasm. Cell walls are formed first against the walls of the seed coat and develop toward the center until the endosperm tissue fills the whole body of the ovule. All grasses that have been studied have a free-nuclear endosperm of the same type.

THE EMBRYO

The fertilized egg elongates and divides into a short four-celled embryo. The cell at the micropylar end sometimes does not divide immediately, but eventually it produces a several-celled suspensor (Figs. 15, 16, 17) that later is almost completely absorbed (Fig. 19). The upper cells of the young embryo soon form a bulbous tip, and the epidermis becomes distinct (Figs. 14, 15). The development of the scutellum is the next evidence of growth (Fig. 16). It is formed by the continued growth of that part of the bulbous embryo, the tip becoming the top of the scutellum and the cells above the suspensor forming the base of the scutellum. The stem tip and the coleoptile develop from the lower half of the outer side of the bulbous portion (Figs. 16, 17) opposite the base of the young scutellum. The scutellum develops rapidly and the basal portion pushes the lower end of the embryo away f om the endosperm (Figs. 18, 19).

The parts of the grass embryo have been much discussed. The opposing views are well presented in the papers of Avery (3) and Boyd (5).

SUMMARY OF ERAGROSTIS EMBRYO SAC DEVELOPMENT

1. There is no tapetal cell.
2. There is a T-form tetrad of megaspores.
3. The inner megaspore develops into the embryo sac.
4. The two- and four-nucleate stages occur as in the Normal-T embryo sac.
5. All four nuclei at the antipodal end of the sac are separated from the rest of the sac as antipodal cells.
6. Two of the nuclei in the micropylar end of the sac fuse in the formation of the endosperm nucleus.
7. The remaining two nuclei in the micropylar end of the sac become the egg and a synergid.
8. The pollen tube enters the sac through the micropyle and fertilization and triple fusion occur.
9. The endosperm is free-nuclear.
10. The seed coats are formed from the outer cell layer of the ovule and the inner integument.
11. The embryo develops as the ordinary grass embryo type.

SUMMARY OF THE GRASS EMBRYO SAC INVESTIGATIONS

1. The antipodals, embryo sacs, *et altera* are summarized in the accompanying tables showing lists of grasses studied and findings in each.
2. Archesporial Cells. Two archesporial cells have been reported in the grass ovules by Fischer (1893), Koernicke (1896), Tannert (1905), Kuwada (1920), Coulon (1923), Schnarf (1926), Anderson (1927).
3. Polyembryony. This condition in the grasses has been seen in *Oryza* by Jones (1928), Kuwada (1910), Komuro (1922); in *Zea* by Brown (1860); in *Poa* by Nishimura (1922) and Anderson (1927); in *Triticum* by Eichinger (1910); in *Eleusine coracana* by Rangaswami (1930). More than one embryo is occasionally found in *Zea* by those testing corn in germinators.
4. Parthenogenesis. This phenomenon was first observed in grasses by Coulon (1927) in *Nardus Stricta*. He found that the pollen was sterile. Gaines and Aase (1926) in *Triticum* and in *Secale*, and Stenar (1935) in *Calamagrostis* have found parthenogenesis.
5. Caryopsis. The fruits of grasses are all the typical caryopsis, and the inner integument forms the seed coat, except that in *Poa* the outer integument is also a part of the seed coat. Stopf (1904) in *Melocanna bambusiodes* of the Bambuseae found that the ovules were "naked, endospermless and viviparous." The embryos drop out of the fleshy fruit, and the fleshy part of the fruit is pericarp. Lyon (1928) has found wheat seeds without embryos. Harlen and Pope (1925) found fruits in barley without embryos and others without endosperm.

SUMMARY OF GRASS EMBRYO SAC INVESTIGATIONS SINCE 1849

Antipodals

	Tapetal Cell	Mega-spores	Embryo Sac	Number of Antipodals	Number of Nuclei	Lateral, or Chalazal	Fertilization	Endo-sperm	Author
1. Bambuseae Bambusa bambos.....	None	Linear-T or T-form?	N. T.	60				Nu. E.	Schnarf, 1926
2. Festuceae Briza media			N. T.	Many	Multinucleate				Fischer, 1880
Briza maxima				Many	Multinucleate	Lateral			Westermaier, 1890
Bromus villosus	None	Linear-T	N. T.	3–10		Lateral	Observed		Beck and Horton, 1932
Bromus marginatus	None	T-form	N. T.	3–10		Lateral	Observed		Beck and Horton, 1932
Bromus rubens	None	Linear-T	N. T.	3–10		Lateral	Observed		Beck and Horton, 1932
Dactylis glomerata			N. T.	5–8	2–3 nucleate				Shadowsky, 1926
Diplachne serotina			N. T.	8–14	Uninucleate	Lateral			Shadowsky, 1926
Eragrostis cilianensis	None	T-form	Fusion of micropylar nuclei	4–6	Uninucleate	Lateral	Observed	Nu. E.	Stover, 1936
Melica nutans	One		Scilla-T	3					Fischer, 1880
Melica altissima	One		Scilla-T	3					Fischer, 1880
Molinia coerulea			N. T.	11–43	Binucleate	Chalazal			Shadowsky, 1926
Poa annua			N. T.	12	2–4 nucleate	Lateral		Nu. E.	Golinski, 1893
Poa Pratensis		Linear-T	N. T.	3–6	Multinucleate	Lateral		Nu. E.	Nishimura, 1922, Anderson, 1927
Poa compressa		Linear-T	N. T.	3–5		Lateral		Nu. E.	Anderson, 1927

SUMMARY OF GRASS EMBRYO SAC INVESTIGATIONS SINCE 1849—[*Continued*]

	Tapetal Cell	Mega-spores	Embryo Sac	Number of Antipodals	Number of Nuclei	Lateral, or Chalazal	Fertilization	Endo-sperm	Author
3. HORDEAE Agropyrum repens	None	Linear-T	N. T.	10–16			Observed; polar nuclei did not fuse	Nu. E.	Mowery, 1929
Elymus arenarius			N. T.	6–12					Hofmeister, 1861, Fischer, 1880
Hordeum sativa distichum				Many		Lateral			Westermaier, 1890
Hordeum tetrastichum				Many					Golinski, 1893
Hordeum murinum				15		Lateral			Lotscher, 1905
Hordeum vulgare			N. T. (H)	6–20			Observed (H.)		Hofmeister, 1861, Lotscher, 1905
Lolium italicum				3	Multinucleate	Lateral			Westermaier, 1890
Lolium tremulentum				3	Multinucleate	Lateral			Westermaier, 1890
Nardus stricta	None	Linear-T	N. T.	Many			Parthenogenic		Coulon, 1923
Secale cereale			N. T. (H)	20		Lateral (H.)	Parthenogenic (Gaines & Aasel, 1926)		Hofmeister, 1858–61, Fischer, 1880, Golinski, 1893, Westermaier, 1890, Lotscher, 1905
Triticum compactum splendens	None	Linear-T	N. T.	36	Multinucleate	Lateral	Observed	Nu. E.	Koernicke, 1896
Triticum repens				10	2–3 nucleate				Lotscher, 1905
Triticum vulgare				Many	Multinucleate		Observed	Nu. E.	Hofmeister, 1861 (1)
	One	Linear-T	N. T.	36+		Lateral	Observed	Nu. E.	Jensen, 1918 (2)
			N. T.	4 (P)			Observed (P.)		Percival 1921 (3)
				8–12	Multinucleate				Golinski, 1893 (4)
Aegilops ovata			N. T.						Schnarf, 1926

SUMMARY OF GRASS EMBRYO SAC INVESTIGATIONS SINCE 1849—[*Continued*]

	Tapetal Cell	Mega-spores	Embryo Sac	Number of Antipodals	Number of Nuclei	Lateral, or Chalazal	Fertilization	Endo-sperm	Author
4. AVENEAE Avena fatua	None	Linear-T	N. T.	25–30	Multinucleate	Lateral		Nu. E.	Cannon, 1910
Avena sativa		Linear-T	N. T.	11–30	Multinucleate	Chalazal	Observed	Nu. E.	Tannert, 1905, Golinski, 1893
Avena pubescens				3	Uninucleate	Lateral			Lotscher, 1905
Avena flavescens			N. T.	5–16	Multinucleate	Lateral			Shadowsky, 1926
Koeleria cristata			N. T.	4	Multinucleate			Nu. E.	Fischer, 1880
5. AGROSTIDAE Agrostis incana				6	Binucleate	Lateral			Shadowsky, 1926
Alepecurus pratensis		Linear-T	N. T.	3	4-nucleate			Nu. E.	Fischer, 1880
Coleanthus subtilis	None	T-form	N. T.	3	Multinucleate			Nu. E.	Schnarf, 1926
Cornupopiae nocturnum (Agrostis perennans)	One		Scilla-T	3	Binucleate	Lateral		Nu. E.	Guignard, 1882
6. ZOYSIEAE Tragus racemosus (Nazia)			N. T.	3-5	Uninucleate	Lateral			Shadowsky, 1926
7. CHLORIDEAE Chloris gayana			N. T.	6	Multinucleate	Chalazal			Shadowsky, 1926
Cynodon dactylon			N. T.	6–10	Multinucleate	Lateral			Shadowsky, 1926
Eleusine indica			N. T.	3					Cummins, 1929
Sesleria coerulea (Bulbilis)		Linear-T	N. T.	3	Multinucleate	Chalazal			Fischer, 1880
8. PHALARIDEAE Ehrharta panicea			N. T.	3–6	Binucleate	Lateral			Fischer, 1880
9. ORYSEAE Oryza sativa			N. T.	3–Many	Multinucleate	Chalazal		Nu. E.	Kuwada, 1910
	None						Observed		Terada, 1928
10. ZIZANIEAE Luzula pilosa (Luziola)		Linear-T	N. T.	3					Fischer, 1880

SUMMARY OF GRASS EMBRYO SAC INVESTIGATIONS SINCE 1849—[*Continued*]

	Tapetal Cell	Mega-spores	Embryo Sac	Number of Antipodals	Number of Nuclei	Lateral, or Chalazal	Fertilization	Endo-sperm	Author
11. MELINIDEAE									
12. PANICEAE Paspalum dilatatum			N. T.	5–14	2–3 nucleate	Chalazal			Shadowsky, 1926
Oplismenus undulatifolium			N. T.	10–18	Binucleate	Chalazal			Shadowsky, 1926
13. ANDROPOGONEAE Andropogon caucasicum			N. T.	4–6	Uninucleate	Lateral			Shadowsky, 1926
Andropogon ischaemum			N. T.	5–16	Uninucleate	Chalazal			Shadowsky, 1926
Eulalia japonica (Miscanthus sinensis)			N. T.	15–24	2–3 nucleate	Chalazal			Shadowsky, 1926
Gynerium argenteum			N. T.	8–13	Uninucleate	Chalazal			Shadowsky, 1926
Sorghum bicolor				Many		Chalazal			Hofmeister, 1842
Sorghum helpense				4					Fischer, 1880 (1)
			N. T.	Many	Multinucleate				Hofmeister, 1861 (2)
							Observed		Stephens, 1934 (3)
Saccharum officinarum	None	Linear-T	N. T.	5	Multinucleate		Observed	Nu. E.	Artswager, 1929
14. TRIPSACEAE Coix lacryma			N. T.	3	Multinucleate	Chalazal			Hofmeister, 1861
Zea mays			N. T.	25		Chalazal			Hofmeister, 1849 (1)
			N. T.						Westermaier, 1890 (2)
			N. T.						Golinski, 1893 (3)
			N. T.						Guignard, 1901 (4)
			N. T.						Lotscher, 1905 (5)
	None	Lily-T	Lily-T				Observed	Nu. E.	Miller, 1920 (6)
	One	Linear-T	N. T.				Observed	Nu. E.	Weatherwax, 1919 (7)

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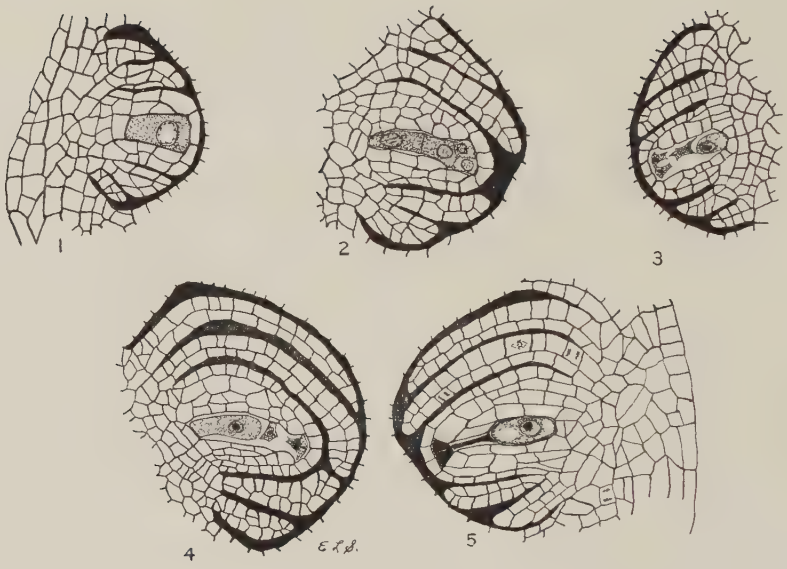
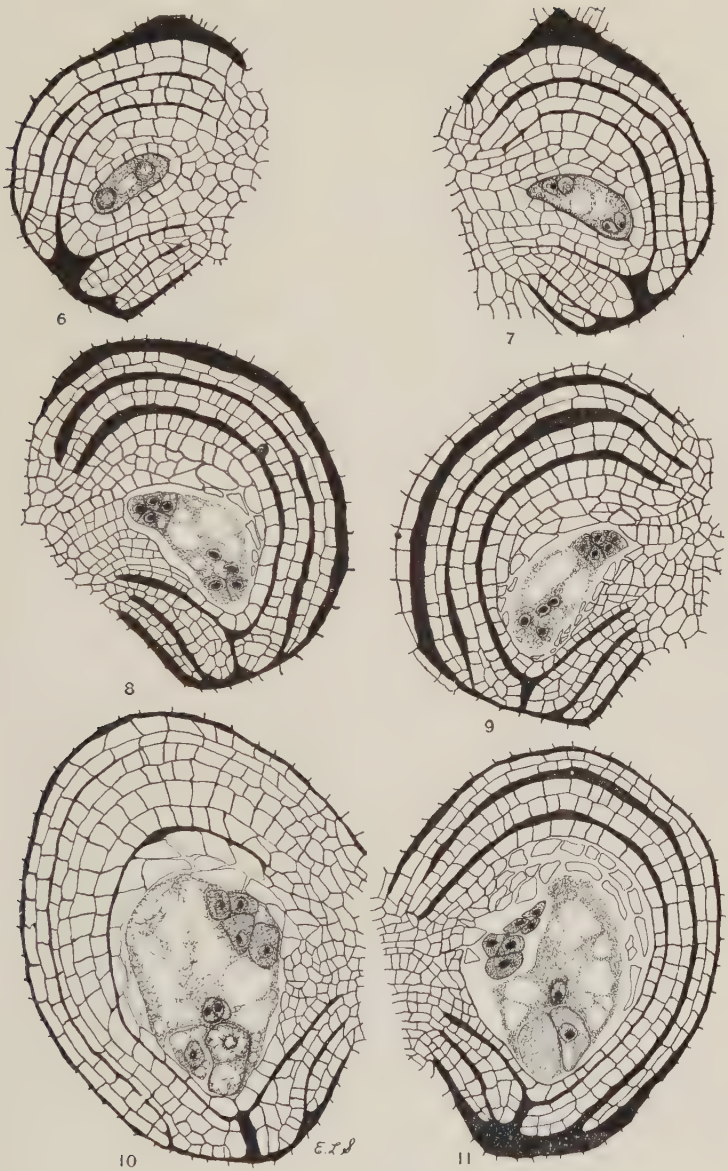


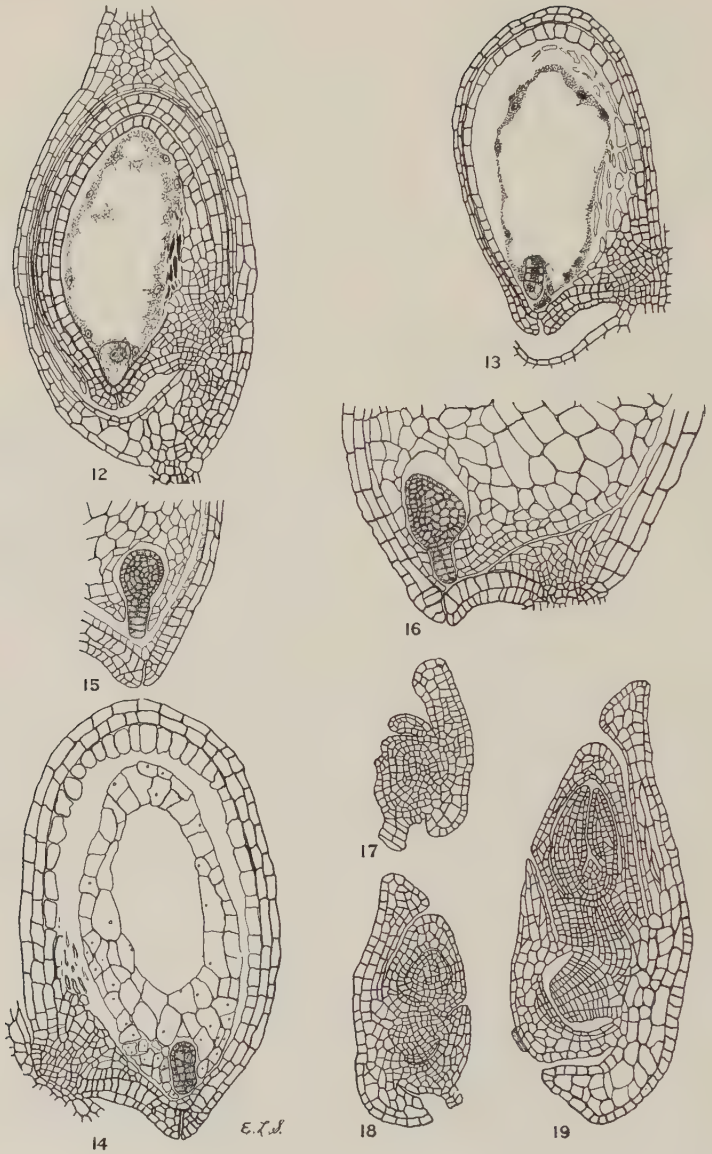
Fig. 1. Section of young ovule showing archesporial cell.
Figs. 2, 3, 4. Sections of young ovules showing T-form tetrad.
Fig. 5. Section of ovule showing persistence of the inner megaspore and the disintegration of the other megaspores.



Figs. 6 and 7. The two and four nucleate embryo sacs.

Figs. 8 and 9. The eight nucleate sac showing the separation of all four antipodals from the rest of the sac.

Figs. 10 and 11. The maturing embryo sac; one synergid, the egg, and the fusion of two micropylar nuclei forming the endosperm nucleus; the antipodals remaining *in situ* as the sac enlarges.



Figs. 12, 13, 14. Sections of ovule showing the fertilized egg and young embryo; the developing endosperm; antipodals in disintegrating stages; the disappearance of the outer integument.

Figs. 15–19. Development of the embryo.

AN ANNOTATED LIST OF THE DRAGONFLIES (ODONATA) OF OHIO

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This list is based on the collections made or examined by the writer during the last several years, and on the records in the literature. The list is doubtless incomplete, as there are some sections of the state that are as yet not adequately worked, but it was thought advisable to publish a preliminary list at this time since no such list has been published in the last 38 years.

The recorded distribution of each species in the state is given by counties. In counties where the writer has not collected the species recorded, the name of the collector is indicated by initials in parentheses following the county record. Records in the literature for counties in which the writer has not collected are similarly indicated. When the collector's initials are followed by an asterisk, specimens are in the writer's collection; otherwise the specimens are in the collection of the collector, or in a collection indicated by initials. When a county record is based on observation only (no specimens) the county name is written in *italics*. The dates following the list of counties are the earliest and latest dates of observation or capture of the species in Ohio.

The following abbreviations are used for collectors and collections:

AW—Alfred Wolf
BB—V. L. and M. J. Bristow
BEM—B. Elwood Montgomery
BPR—Ben P. Ramsey
CFW—Charles F. Walker
CHK—Clarence H. Kennedy
CU—Clem Uller
DJ—Dale W. Jenkins
DM—W. Donald Murray
DS—Dale Snavely
EB—Emerson Ball
EBW—E. B. Williamson
EMS—Earl M. Sprunger
EPB—E. P. Breakey
EPF—E. P. Fuchs
EST—Edward S. Thomas
FLJ—F. L. Jeffries
GG—Gene Good
GH—Gerald Huffman
GRO—George R. Owen
HAW—Harold A. Waters
HK—R. Henry Kyle
JAS—James A. Strasburg
JB—Joe Bailey
JGH—James G. Haub
JS—John Stanley

JSH—James S. Hine
JST—John S. Thomas
LB—Lawrence Beery, Jr.
LBa—Lorain Basinger
LOC—L. O. Clevenger
LYL—L. Y. Lancaster
MBT—Milton B. Trautman
MDN—Mary D. Neiswander
MDR—Mary D. Rogick
MEC—Meril E. Crago
NJG—N. J. Geiler
OSM—Ohio State (Natural History) Museum
OSU—Collection of Dept. Zoology and Entomology, Ohio State University
RCO—Raymond C. Osburn
REK—R. E. Kunze
RG—Robert Goslin
RTE—Ray T. Everly
SL—Simon Levine
UM—Collection of Museum of Zoology, Univ. of Michigan
WED—Weldon E. Diller
WFH—W. F. Henninger
WRP—William R. Piper

LIST OF SPECIES

Family Aeschnidae

1. *Tachopteryx thoreyi* Hagen.
Champaign, Fairfield (JSH, OSM), Guernsey (HAW*), Hocking, Summit (JSH, OSU). May 12 to Aug. 11.

2. *Negomphoides obscura* Rambur.[1]
Gallia, Lawrence (OSU). May 30 to June 23.

3. *Hagenius brevistylus* Selys.
Ashland (OSU), Delaware, Franklin, Holmes (EST, OSM). June 3 to Aug. 4.

4. *Ophiogomphus rupinsulensis* Walsh.
Franklin, Holmes (CFW, OSM), Portage (Osburn and Hine, 1900). May 17 to July 22.

5. *Erpetogomphus designatus* Hagen.
Hamilton (Hine, 1913). July 26.

6. *Gomphus* (*Gomphurus*) *abbreviatus* Hagen.
Ashland (Hine, 1900 and 1913). June 10 to June 23.

7. *Gomphus* (*Stylurus*) *amnicola* Walsh.
Hamilton (Hine, 1913). May 5 to July 25.

8. *Gomphus* (*Gomphurus*) *crassus* Hagen.
Delaware, Franklin. May 23 to June 13.

9. *Gomphus* (*Gomphus*) *exilis* Selys.
Erie (Hine, 1901), Franklin (Kellicott, 1899), Logan, Portage (EST*), Summit (JSH, OSM), Vinton. May 9 to July 19.

10. *Gomphus* (*Gomphurus*) *fraternus* Say.
Coshocton, Erie (BEM*), Franklin, Gallia, Logan (JSH, OSM), Ottawa (BEM), Portage (Osburn and Hine, 1900), Ross, Vinton (OSU). May 28 to July 8.

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[1]This species is placed in the genus *Negomphoides* on the authority of Cowley (1934, p. 244).

11. *Gomphus* (*Arigomphus*) *furcifer* Hagen.
Erie (OSU), Fairfield (Kellicott, 1899), Portage (Kellicott, 1899). June 14 to July 2.

12. *Gomphus* (*Gomphus*) *graslinellus* Walsh.
Auglaize, Delaware, Franklin, Greene (HK*), Hocking, Jackson, Licking, Logan, Union, Van Wert (GG). May 21 to July 1.

13. *Gomphus* (*Gomphurus*) *lineatifrons* Calvert.
Ashland (OSU), Franklin, Portage (Osburn and Hine, 1900, as *Gomphus dilatatus* Rambur). May 24 to June 14.

14. *Gomphus* (*Gomphus*) *lividus* Selys.
Auglaize (JAS), Erie (BEM), Fairfield, Gallia, Geauga (MEC*), Greene, Hocking (CFW, OSM), Holmes (JSH, OSM), Knox (EBW, UM), Lawrence (OSU), Licking, Monroe (CFW, OSM), Portage (Osburn and Hine, 1900), Sandusky (BEM). May 11 to July 14.

15. *Gomphus* (*Stylurus*) *notatus* Rambur.
Lawrence (OSU). May 30.

16. *Gomphus* (*Stylurus*) *plagiatus* Selys.
Erie (EBW, UM), Fulton (Kellicott, 1899), Ottawa (Kennedy, 1922). June 20 to July 1.

17. *Gomphus* (*Gomphus*) *quadricolor* Walsh.
Coshocton, Franklin (OSU), Portage (Osburn and Hine, 1900), Tuscarawas. May 30 to June 13.

18. *Gomphus* (*Gomphus*) *spicatus* Hagen.
Erie (OSU), Logan, Portage (Osburn and Hine, 1900). May 7 to June 11.

19. *Gomphus* (*Stylurus*) *spiniceps* Walsh.
Fairfield (Kellicott, 1899), Ottawa (BEM), Summit (OSU). June 27 to Sept. 26.

20. *Gomphus* (*Gomphurus*) *vastus* Walsh.
Coshocton, Erie (OSU), Franklin (OSU), Ottawa (BEM*), Seneca (DS). May 30 to Sept. 15.

21. *Gomphus* (*Gomphurus*) *ventricosus* Walsh.
Coshocton, Franklin. May 23 to May 30.

22. *Gomphus* (*Arigomphus*) *villosipes* Selys.
Franklin (OSU), Geauga (MEC*), Knox (GRO*), Perry (JSH, OSM), Sandusky, Summit (JSH, OSU). May 10 to June 17.

23. *Gomphus* (*Gomphurus*) *viridifrons* Hine.
Ashland (JSH, OSU—type), Coshocton (JSH*), Logan (JSH, OSM). June 10 to June 14.

24. *Dromogomphus spinosus* Selys.
Coshocton, Crawford (OSU), Erie (Hine, 1901), Franklin, Portage (Osburn and Hine, 1900). May 30 to June 28.

25. *Dromogomphus spoliatus* Hagen.
"Common in northwestern Ohio along the Maumee River and its tributaries, and the Ohio canal." (Kellicott, 1899, p. 73).

26. *Lanthus albistylus* Hagen.
Ashland (JSH, OSU), Delaware, Franklin. June 3 to June 13.

27. *Gomphaeschna furcillata* Say.
Franklin (OSU). June 13 to June 15.

28. *Basiaeschna janata* Say.
Delaware, Fairfield, Franklin, Fulton (JSH, OSM), Greene (HK*), Licking, Morrow, Portage (Osburn and Hine, 1900), Tuscarawas. May 4 to June 13.

29. *Boyeria grafiana* Williamson.
Ashtabula (OSU). Sept.

30. *Boyeria vinosa* Say.
Belmont (BPR*), Coshocton (DJ), Fairfield (RG, OSM), Franklin, Geauga (MEC*), Hocking (EST, OSM), Jackson, Knox (Williamson, 1907), Logan, Seneca (OSU). June 22 to Sept. 1.

31. *Anax junius* Drury.
Ashtabula (JSH, OSU), Auglaize (JAS), Champaign, Coshocton (DJ), *Darke* (DJ), Delaware (JCP), Erie (BEM), Fairfield, Franklin, Geauga, Greene (HK*), *Holmes*, *Jackson*, Lawrence, Licking, Logan, Lucas (JB*), Ottawa, *Perry*, Pickaway, *Pike*, Portage (Osburn and Hine, 1900), Putnam (WED*), Sandusky, Shelby, *Vinton*, *Washington*, Wayne. April 7 to Oct. 8.

32. *Anax longipes* Hagen.
Erie (OSU), Hamilton (Kellicott, 1899), *Wayne* (BEM). June 22 to July 25.

33. *Nasiaeschna pentacantha* Rambur.
Portage (OSU). June 1 to June 22.

34. *Epiaeschna heros* Fabricius.
Auglaize (WFH, OSM), Erie (Hine, 1901), Franklin (CHK*), Licking (SL*), Ottawa (MDR*), Portage (Osburn and Hine, 1900). April 25 to July 10.

35. *Aeschna clepsydra* Say.
Kellicott, 1899, p. 84. (No locality given.)

36. *Aeschna constricta* Say.
Erie (CU, UM), Franklin (OSU), Logan, Ottawa (Kennedy, 1922). Aug. 10 to Sept. 23.

37. *Aeschna mutata* Hagen.
Franklin, Ottawa (CHK*), Portage (OSU). June 10 to June 27.

38. *Aeschna umbrosa* Walker.
Allen (JAS), Butler (EBW*), Champaign, Columbiana (Walker, 1912), Coshocton (DJ), Franklin, Geauga (MEC*), Logan, Medina (OSU), Shelby (DM*), Summit (OSU). July 21 to Oct. 13.

39. *Aeschna verticalis* Hagen.
Erie (Hine, 1901), Franklin (OSU), Summit (OSU). Sept. 19 to Oct. 6.

40. *Cordulegaster diastatops* Selys.
Champaign, Geauga (MEC*), Licking, Portage (JAS*). May 21 to July 7.

41. *Cordulegaster erroneus* Hagen.
Fairfield (OSU), Hocking (JST, OSM). July 5 to July 30.

42. *Cordulegaster maculatus* Selys.
Hocking. June 2 to June 17.

43. *Cordulegaster obliquus* Say.
Ashtabula (Kellicott, 1899), Guernsey (AW*). June to July.

Family Libellulidae

44. *Macromia illinoiensis* Walsh.
Adams (JSH, OSM), Erie (JSH, UM), Franklin (JSH, OSU), Hocking, Morgan (MBT, OSM), Ottawa (Kennedy, 1922), Pike (JS*), Portage (Osburn and Hine, 1900), Ross, *Tuscarawas*. May 3 to Aug. 7.

45. *Macromia taeniolata* Rambur.
Henry (JSH, UM), Lucas (OSU). July 9 to Aug. 1.

46. *Didymops transversa* Say.
Franklin (OSU), Vinton. April 25 to June 6.

47. *Neurocordulia obsoleta* Say.
Hamilton (OSU). June 15.

48. *Neurocordulia yamaskensis* Provancher.
Erie (Hine, 1901), Ottawa (OSU). June 26 to June 28.

49. *Epicordulia princeps* Hagen.
Coshocton (DJ), Erie (OSU), Fairfield, Franklin (EMS*), *Holmes*, Licking, Logan, Ottawa (Kennedy, 1922), *Perry*, Portage (Osburn and Hine, 1900). June 2 to Sept. 14.

50. *Tetragoneuria cynosura* Say.
Ashtabula (DJ), Champaign (CHK), *Coshocton* (DJ), Delaware (Kellicott, 1899, as *T. semiaqua* Burm.), Erie (Hine, 1901), Fairfield, Franklin, Geauga (MEC*), Hamilton (Muttkowski, 1911), Knox (Muttkowski, 1911), Licking (MDN, OSM), Logan, Mahoning (Muttkowski, 1911), Muskingum, Perry, Portage (JSH, OSU), Vinton. May 18 to Aug. 10.

51. *Somatochlora hineana* Williamson.
Logan (Williamson, 1931; type locality). June 7 to July 4.

52. *Somatochlora tenebrosa* Say.
Champaign, Coshocton (DJ*), Hocking (JSH, OSM), Jackson (CFW, OSM). July 1 to Aug. 4.

53. *Nannothemis bella* Uhler.
Champaign. June 6 to Aug. 14.

54. *Perithemis tenera* Say.
Belmont (BPR*), Clark, Coshocton (DJ*), Darke (DJ*), Erie (BEM), Fairfield, Franklin, *Geauga*, Greene, Hamilton (JGH*), Holmes, Lawrence, Licking, Logan, Lucas (JB, UM), Ottawa, Portage, Sandusky, *Shelby*, *Trumbull*, Vinton. June 11 to Sept. 14.

55. *Celithemis elisa* Hagen.
Ashtabula (DJ*), Champaign (JB*), Clark, Erie (BEM*), Fulton (OSU), Logan, Ottawa (BEM), Portage (Osburn and Hine, 1900), Vinton, *Washington*. June 6 to Aug. 15.

56. *Celithemis eponina* Drury.
Champaign (JB, UM), *Clark*, Erie (OSU), Franklin (JAS), Geauga, Licking, Logan, Miami (EST, OSM), Portage (Osburn and Hine, 1900). June 13 to Aug. 10.

57. *Celithemis monomelaena* Williamson.
Franklin (Williamson, 1910), Hamilton (Williamson, 1910), Portage (OSU), Summit (OSU). June 18 to Aug. 23.

58. *Erythrodiplax minuscula* Rambur.
Vinton. June 23.

59. *Erythrodiplax umbrata* Linnaeus.
Champaign. June 11.

60. *Ladona julia* Uhler.
Portage (OSU). June 18 to June 22.

61. *Libellula* (*Holotania*) *auripennis* Burmeister.
Hamilton (Kellicott, 1899), *Vinton*. June 23.

62. *Libellula* (*Holotania*) *cyanea* Fabricius.
Knox (OSU), Vinton. June 6 to July 12.

63. *Libellula* (*Holotania*) *incesta* Hagen.
Erie (OSU), Geauga, Portage (Osburn and Hine, 1900). June 26 to Aug. 1.

64. *Libellula* (*Holotania*) *luctuosa* Burmeister.
Ashtabula (DJ*), Belmont (BPR*), Champaign (JB, UM), *Clark*, Coshocton (DJ*), Darke (DJ*), Delaware, Erie (BEM*), Fairfield, Franklin, Geauga, Greene, *Holmes*, Jackson (EST, OSM), Licking, Logan, Lucas (JB, UM), Mahoning, Marion (BEM), *Miami*, Ottawa (Kennedy, 1922), Pike (CFW, OSM), Portage (EST, OSM), *Ross*, Sandusky, *Stark*, Trumbull, Van Wert (GG), Vinton. May 28 to Sept. 11.

65. *Libellula* (*Plathemis*) *lydia* Drury.
Adams, Ashtabula, Auglaize, Belmont (BPR*), Carroll, Champaign, *Clinton*, Coshocton (FLJ), Delaware, Erie, Fairfield, *Fayette*, Franklin, *Gallia*, Geauga, Greene, *Guernsey*, Hocking, Knox (GRO*), Licking, Logan, Lucas (JB, UM), Mahoning, Marion (BEM), Mercer, Montgomery, Morrow (REK), Muskingum (JST, OSM), Ottawa, Pickaway, Portage (Osburn and Hine, 1900), Ross, Sandusky, Shelby, *Stark*, Van Wert (GG), Vinton, *Washington*. May 13 to Aug. 30.

66. *Libellula* (*Neotetrum*) *pulchella* Drury.
Adams, *Ashland*, Ashtabula, *Auglaize*, Belmont (BPR*), *Carroll*, Champaign, *Clark*, *Coshocton* (DJ), *Darke* (DJ), Delaware, Erie, Fairfield, *Fayette*, Franklin, Geauga, Greene, Hocking, Holmes, Jackson, Knox, Lawrence, Licking, Logan, Lucas (JB, UM), *Mahoning*, Marion (BEM), Mercer, Ottawa, Pickaway, *Pike*, Portage (Osburn and Hine, 1900), Putnam (LBa), Ross (EPF), Sandusky, Scioto, Shelby, Summit (LB), Trumbull, Van Wert (GG), Vinton, *Washington*, Wayne (BEM). May 9 to Aug. 30.

67. *Libellula* (*Libellula*) *quadrimaculata* Linnaeus.
Erie (OSU), Knox (Hine, 1899). June 12 to June 22.

68. *Libellula* (*Eolibellula*) *semifasciata* Burmeister.
Ashtabula (DJ*), Champaign, Erie (OSU), Fairfield, Franklin, Hocking, Ottawa (Kennedy, 1922), Portage (Osburn and Hine, 1900), Vinton. May 2 to July 15.

69. *Libellula* (*Holotania*) *vibrans* Fabricius.
Fairfield (Kellicott, 1899), Franklin (OSU), Logan (JSH, OSM). June to July.

70. *Sympetrum ambiguum* Rambur.
Champaign, Erie, Fairfield, Franklin, *Holmes*, Licking, Logan, Ottawa, Perry (EST, OSM), Shelby. July 1 to Sept. 10.

71. *Sympetrum corruptum* Hagen.
Ashtabula, Erie (BEM), Franklin, Fulton (OSU), Greene (HK*), Licking, Putnam (WED*). April 18 to Aug. 9.

72. *Sympetrum obtrusum* Hagen.
Ashtabula, Erie (OSU), Franklin, Licking (JSH), Logan, Lucas (JB, UM), Ottawa, Scioto (OSU), Shelby, Vinton. June 23 to Sept. 9.

73. *Sympetrum rubicundulum* Say.
Ashtabula, Champaign, Coshocton (EPB*), Erie (OSU), Fairfield, Franklin, Geauga, Highland (JSH, OSM), Licking, Logan, Lucas (JB, UM), Morrow (RTE*), Ottawa, Perry (EST, OSM), Portage (Osburn and Hine, 1900), Sandusky, Shelby, Stark, Summit (OSM), Vinton. June 10 to Aug. 26.

74. *Sympetrum semicinctum* Say.
Belmont (BPR*), Champaign, Erie (OSU), Franklin (Kellicott, 1899), Geauga, Logan, Lucas (JB, UM), Summit (JSH, OSM). July 2 to Aug. 26.

75. *Sympetrum verum* Bartenef.
"Ohio." (Bartenef, 1915.)

76. *Sympetrum vicinum* Hagen.
Athens (EB), Butler (EBW*), Champaign, Coshocton (EPB*), Erie (BEM*), Fairfield (JAS), Franklin, Geauga, Holmes, Licking (JSH, OSM), Logan, Ottawa, Perry (EST, OSM), Portage, Trumbull, Vinton, Washington. June 29 to Nov. 7.

77. *Leucorrhinia intacta* Hagen.
Champaign, Erie (BEM*), Franklin, Geauga, Licking, Logan, Ottawa (Kennedy, 1922), Portage (JSH, OSM). May 9 to Aug. 1.

78. *Pachydiplax longipennis* Burmeister.
Ashtabula, Auglaize, Champaign, Coshocton, Delaware, Erie (BEM), Fairfield, Franklin, Geauga, Greene, Hocking, Holmes, Lawrence, Licking, Logan, Lucas (JB, UM), Miami (EST, OSM), Morrow (REK), Muskingum (JST, OSM), Ottawa, Perry (EST, OSM), Pickaway, *Pike*, Portage (Osburn and Hine, 1900), Sandusky, Shelby, *Trumbull*, Vinton, Washington. May 6 to Sept. 9.

79. *Erythemis simplicicollis* Say.
Champaign (JB, UM), *Clark*, Coshocton (DJ*), *Darke* (DJ), Erie (BEM), Fairfield, Franklin, Greene (HK*), Holmes, Licking, Logan, Lucas (JB, UM,) Miami (EST, OSM), Ottawa, Perry, Portage (JAS), Sandusky, Shelby, Stark, *Trumbull*, Vinton. May 19 to Oct. 16.

80. *Pantala flavescens* Fabricius.
Ashtabula, Erie (Hine, 1901), Fulton (OSU), Logan (DM), Pickaway (LOC), Ottawa (OSU). July 2 to Oct. 17.

81. *Pantala hymenaea* Say.
Adams, *Athens*, Franklin (LOC), Logan (MBT, OSM), Shelby (Kellicott, 1899), *Washington*. April 3 to June 29.

82. *Tramea carolina* Linnaeus.
Clark, Erie (Hine, 1901a), Franklin, *Licking*, Ottawa, Vinton, *Washington*. May 6 to Aug. 14.

83. *Tramea lacerata* Hagen.
Ashtabula (DJ), Champaign, *Clark*, *Coshocton* (DJ), Delaware, Erie (BEM*), Fairfield, Franklin, Greene, *Holmes*, *Jackson*, Licking, Logan, Lucas (JB, UM), Ottawa, Perry, Pickaway, Pike, Portage (Osburn and Hine, 1900), Vinton, *Washington*. May 6 to Oct. 11.

84. *Tramea onusta* Hagen.
Cuyahoga (OSU), Erie, Franklin (JS), Greene (HK*), Hamilton (Kellicott, 1899), Ottawa. May 7 to Aug. 26.

Family Calopterygidae

85. *Calopteryx aequabile* Say.
Portage (OSU), Summit (OSU). June 18 to June 26.

86. *Calopteryx angustipenne* Selys.
Ashland (OSU). June 10 to June 14.

87. *Calopteryx maculatum* Beauvais.
Adams, Ashland, Ashtabula, Auglaize, Champaign, Clark, Clinton, Coshocton, Delaware, Erie (BEM*), Fairfield, Franklin, Gallia, Geauga (MEC*), Greene, Guernsey, Hamilton (Huggins, 1927), Highland, Hocking, Holmes, Jackson, Lake (BEM), Licking, Logan, Lucas (JB, UM), Marion (BEM), Morrow, Perry, Portage, Ross, Trumbull, Union, Vinton, Wayne (BEM). May 21 to Aug. 18.

88. *Hetaerina americana* Fabricius.
Ashland, Auglaize, Belmont (BPR*), Champaign (JB, UM), Clark, Delaware, Erie (BEM*), Fayette, Franklin, Greene, Highland, Hocking, Lake (BEM), Licking, Logan, Madison, Mahoning, Paulding (GG), Portage (Osburn and Hine, 1900), Ross, Scioto (OSU), Shelby, Summit (LB). May 7 to Oct. 7.

89. *Hetaerina titia* Drury.
Fairfield (OSU). Sept. 28.

Family Coenagrionidae

90. *Archilestes grandis* Rambur.
Butler (Williamson, 1930), Preble (EST, OSM), Montgomery (Cotterman, 1930). Sept. 21 to Oct. 11.

91. *Lestes congener* Hagen.
Franklin (OSU), Licking (JSH, OSM), Logan. July 3 to Sept. 28.

92. *Lestes disjunctus* Selys.
Ashtabula, Columbiana (EBW, UM), Delaware (GH), Erie (RCO, UM), Fairfield, Franklin, Geauga (MEC*), Ottawa (UM). May 9 to Aug. 14.

93. *Lestes eurinus* Say.
Erie (OSU), Franklin, Logan, Portage (Hine 1900 and 1913). May 24 to July 14.

94. *Lestes forcipatus* Rambur.
Ashtabula, Auglaize (JAS), Champaign, Erie (OSU), Fairfield, Franklin, Hocking (JST, OSM), Knox (GRO*), Lawrence, Logan, Lucas (JB, UM), Ottawa, Portage (JSH, UM). April 28 to Aug. 18.

95. *Lestes inaequalis* Walsh.
Champaign (JB*), Erie (OSU), Fairfield (OSU), Licking (WRP*), Logan (WRP*), Morrow (REK), Portage (RCO, UM), Stark. June 16 to Aug. 10.

96. *Lestes rectangularis* Say.
Ashtabula, Champaign, Coshocton, Erie, Fairfield, Franklin, Geauga, Greene, Holmes, Knox (EBW, UM), Licking, Logan, Lucas (JB*), Muskingum (DJ), Ottawa, Portage, Sandusky, Shelby, Stark, Trumbull, Vinton, Washington. May 30 to Aug. 26.

97. *Lestes uncatus* Kirby.
Ashtabula, Champaign, Coshocton (JSH, OSM), Erie (BEM), Fairfield, Franklin, Geauga, Logan, Lucas (JB, UM), Mahoning (UM), Morrow (REK), Ottawa (Kennedy, 1922), Portage (JSH, UM). June 10 to Aug. 1.

98. *Lestes unguiculatus* Hagen.
Ashtabula, Champaign, Erie (OSU), Franklin, Logan, Ottawa, Summit (LB), Trumbull. July 1 to Aug. 22.

99. *Lestes vigilax* Hagen.
Erie (OSU), Portage. July 4 to Aug. 1.

100. *Argia apicalis* Say.
Adams, Athens, Auglaize, Belmont (BPR*), Delaware, Erie (BEM*) Fairfield, Franklin, Gallia, Greene, Licking, Logan, Lucas (JB, UM), Mahoning, Montgomery, Muskingum, Ottawa, Portage (Osburn and Hine, 1900), Ross, Sandusky, Scioto (NJG), Shelby, Stark, Summit (LB), Vinton. June 4 to Sept. 4.

101. *Argia bipunctulata* Hagen.
Champaign. June 3 to Aug. 22.

102. *Argia moesta* Hagen.
Adams, Ashland, Belmont (BPR*), *Clark*, *Coshocton*, Delaware (DM), Erie (BEM), Fairfield, Franklin, Greene, Highland, Holmes (EST, OSM), *Hocking*, Knox, Lake (BEM), Licking, Logan, Mahoning, Miami, *Montgomery*, Ottawa, Portage (Osburn and Hine, 1900), Ross, Shelby, Tuscarawas, Van Wert (GG). May 30 to Aug. 24.

103. *Argia sedula* Hagen.
Adams, Athens, Erie (Hine, 1901), Fayette, Franklin, Fulton (OSU), Greene, Hocking, Knox (FLJ), Licking, Madison, Ross, Shelby. June 12 to Aug. 24.

104. *Argia tibialis* Rambur.
Adams, Athens, Delaware, Erie (BEM), Fairfield, Franklin, Gallia, Greene, Highland, *Hocking*, *Holmes*, Jackson, Knox (FLJ), Licking, Logan, Montgomery, Pickaway, Portage (Osburn and Hine, 1900), Ross, Sandusky, Trumbull, Vinton. May 30 to July 29.

105. *Argia violacea* Hagen.
Adams, Ashland, Ashtabula, Auglaize, Champaign, Clark, Clinton, Delaware, Erie (BEM), Fairfield, Franklin, Geauga, Greene, Highland, Holmes, Knox, Lake (BEM), Licking, Logan, Mahoning, Miami, Morrow, Perry, Pickaway, Portage, Ross, Sandusky, Stark, Trumbull, Vinton, Wayne (BEM). May 26 to Sept. 15.

106. *Amphiagrion saucium* Burmeister.
Champaign, Coshocton, Delaware, Erie (BEM), Fairfield, Franklin, Fulton (OSU), Geauga (MEC*), Hocking, Knox, Licking, Logan, Pickaway, Portage (JST, OSM), Wayne (BEM). May 10 to Aug. 13.

107. *Nehalennia gracilis* Morse.
Champaign, Geauga, Knox, Licking. May 30 to Aug. 1.

108. *Nehalennia irene* Hagen.
Ashtabula, Champaign, Erie (Hine, 1901a), Franklin, Licking, Logan, Ottawa (Kennedy, 1922), Portage (Osburn and Hine, 1900), Wayne (BEM*). May 17 to Aug. 1.

109. *Chromagrion conditum* Hagen.
Champaign, Delaware, Franklin, Geauga (MEC*), Greene, Licking, Ottawa (CHK), Portage (Osburn and Hine, 1900), Vinton. May 20 to July 12.

110. *Enallagma antennatum* Say.
Auglaize, Clark, Clinton, Delaware, Erie, Fairfield, Fayette, Franklin, Greene, Knox, Licking, Logan, Lucas (JB, UM), Mercer, Morrow, Muskingum, Perry, Portage (JSH, OSM), Sandusky, Shelby, Union, Wayne (BEM). May 20 to Aug. 11.

111. *Enallagma aspersum* Hagen.
Erie (OSU), Franklin, Geauga, Lawrence, Logan, Washington. May 7 to Aug. 1.

112. *Enallagma boreale* Selys.
Erie (BEM), Franklin. May 14 to June 20.

113. *Enallagma carunculatum* Morse.
Auglaize, Champaign, Clark, Erie (OSU), Holmes, Licking, Logan, Lucas (JB*), Mercer (Kellicott, 1899), Ottawa, Portage (Osburn and Hine, 1900), Stark. June 3 to Sept. 11.

114. *Enallagma civile* Hagen.
Ashtabula, Belmont (BPR*), Butler (EBW, UM), Clark, Darke (DJ*), Delaware, Erie, Fairfield, Fayette, Franklin, Greene, Holmes, Knox (GRO*), Licking, Logan, Lucas (JB, UM), Ottawa, Portage (Osburn and Hine, 1900), Sandusky, Tuscarawas, Washington. May 4 to Oct. 11.

115. *Enallagma divagans* Selys.
Clinton, Delaware, Fairfield, Greene, Jackson, Logan, Morrow, Portage (JSH, OSM), Vinton. June 3 to June 29.

116. *Enallagma doubledayi* Selys.
Franklin (OSU). May 4.[1]

117. *Enallagma ebrium* Hagen.
Erie (BEM), Franklin, Geauga (MEC), Logan (JSH, OSM), Ottawa (BEM*), Portage (JSH, OSM), Sandusky. May 7 to July 15.

118. *Enallagma exsulans* Hagen.
Adams, Ashland, Athens, Auglaize, Butler (EBW, UM), Clark, Clinton, Delaware, Erie, Fairfield, Fayette, Franklin, Greene, Highland, *Hocking*, Jackson, Lake (BEM), Knox, Licking, Logan, Lucas (JB, UM), Madison, Mahoning, Miami, Montgomery, Morrow, Muskingum, Ottawa, Perry, Pickaway, Portage (Osburn and Hine, 1900), Ross, Sandusky, Stark, Trumbull, Tuscarawas, Union, Van Wert (GG), Vinton. May 17 to Sept. 4.

119. *Enallagma geminatum* Hagen.
Champaign (JB, UM), Erie (Hine, 1901), Franklin, Fairfield, Holmes, Licking, Logan, Perry, Portage (Osburn and Hine, 1900), Stark, Summit. May 14 to Sept. 26.

120. *Enallagma hageni* Walsh.
Franklin, Geauga (MEC*), Logan, Ottawa (Kennedy, 1922), Portage (JSH, OSM). June 11 to June 29.

121. *Enallagma signatum* Hagen.
Ashtabula, Champaign, Erie (BEM), Fairfield, Franklin (JAS), Holmes, Licking, Logan, Madison, Ottawa, Portage (Osburn and Hine, 1900), Shelby, Stark, Summit. May 21 to Sept. 26.

122. *Enallagma traviatum* Selys.
Fairfield (DJ*), Hamilton (OSU), Licking, Logan, Portage, Summit (Kellicott, 1899). June 1 to Aug. 1.

123. *Enallagma vesperum* Calvert.
Champaign (BB*), Erie (OSU), Greene, Licking, Logan, Ottawa, Portage (Osburn and Hine, 1900, as *E. pollutum* Hagen), Stark. May 31 to Aug. 25.

124. *Ischnura posita* Hagen.
Ashtabula, Butler (EBW, UM), Champaign, Clinton, Coshocton, Erie (BEM), Fairfield, Fayette, Franklin, Geauga, Greene, Holmes, Jackson, Lawrence, Licking, Logan, Madison, Montgomery, Morrow (DJ*), Muskingum, Perry, Pickaway, Portage (Osburn and Hine, 1900, as *Nehalennia posita*), Shelby, Summit, Union, Vinton, Wayne (BEM). April 23 to Oct. 11.

125. *Ischnura prognatha* Hagen.
Hocking (CHK, OSU). April 20.

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[1]This species was reported from Logan County in my 1930 paper (Borror, 1930, p. 415), but the specimens were misidentified. They were *E. carunculatum* Morse.

126. *Ischnura verticalis* Say.

Ashtabula, Auglaize, Belmont (BPR*), Butler (EBW, UM), Champaign, Clark, Clinton, Coshocton, Darke (DJ*), Delaware, Erie, Fairfield, Fayette, Franklin, Gallia, Geauga, Greene, Hocking, Holmes, Jackson, Knox, Lake (BEM), Licking, Logan, Lucas (JB*), Madison, Mahoning, Mercer, Miami, Morrow, Muskingum, Ottawa, Perry, Pickaway, Pike, Portage, Ross, Sandusky, Shelby, Stark, Summit, Trumbull, Tuscarawas, Union, Van Wert (GG), Vinton, Washington, Wayne (BEM). April 30 to Oct. 11.

127. *Anomalagrion hastatum* Say.

Champaign, Erie (BEM), Fairfield, Franklin, Fulton (OSU), Logan, Ottawa (LYL), Pike, Shelby, Vinton. May 6 to Aug. 24.

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BOOK NOTICES

Queen Becomes Handmaiden

Eric Temple Bell, who several years ago wrote a delightful treatise on mathematics, entitled "The Queen of the Sciences," has now written an account of mathematics from a different viewpoint. This he calls "The Handmaiden of the Sciences." It is quite as delightful as his older books, though not so easy to read. Numerous examples are given of the predictive ability of mathematics in the natural sciences. The calculus is extensively treated, and some consideration is given to geometry, waves and vibrations, and probability. Throughout the book the place of mathematics in serving, stimulating and predicting for the sciences is emphasized. Although the reader is frequently exasperated by the fact that he is never quite sure when the author is serious and when he is laughing at him, the book is highly recommended to scientists for its informative entertainment.—L. H. S.

The Handmaiden of the Sciences, by Eric Temple Bell. viii+216 pp. Baltimore, The Williams and Wilkins Co., 1937. $2.00.

Weather

A much-needed, up-to-date textbook in meteorology, serving ideally the needs of the modern elementary college course in this country, has arrived in "Weather Elements," by Thomas A. Blair. The author, who is an experienced meteorologist with the United States Weather Bureau, as well as Assistant Professor of Meteorology at the University of Nebraska, has keenly sensed the problem of presenting the science of the weather before an average, non-specialized reader, and has written his work in a fascinating, though scientific language, stripped of highly technical phrases and mathematical equations. The work is distinctly modern as demonstrated by the inclusion of aeronautical information, latest developments in researches of the stratosphere, and principles of air-mass analysis and their application in weather forecasting. It is quite complete, though void of excessive descriptive matter. It is reasonably well illustrated, with a series of excellent cloud photographs as a feature. Four useful appendices include a well-rounded bibliography, and various tables and charts. The two short chapters dealing with climate might well have been omitted, at least from the viewpoint of the teacher of courses in that field.—PARIS B. STOCKDALE.

Weather Elements—A Textbook in Elementary Meteorology, by Thomas A. Blair. xv+401 pp., 107 figs. New York, Prentice-Hall, Inc., 1937. $4.00.

Elementary Electricity

"Electricity and Magnetism" is a textbook which should serve excellently as a text for a beginning course in Electrical Engineering or as a replacement for these topics in the ordinary course in College Physics.

The book is typical of English texts in the wealth of material covered and the clarification of written material by the use of solved examples. In the latter part of the work a slight knowledge of the elementary calculus is indicated, but the parts which embody these necessities may be omitted in a class not so prepared.

It might have been better if the first chapter (an introduction to supply the student with mechanical principles) had been omitted. This chapter contains a discussion of dimensions never mentioned again in the entire work, and without any use (so far as I can see) in an electrical problem, where their introduction always seems to be artificial, and serves at best as a poor check on the results which must be obtained in some other way.

The explanations and the solutions of the examples are very clear and the book appears to be very teachable. There is an excellent index and a large number of problems whose answers are given in a supplement at the end of the book.

—J. B. GREEN.

Electricity and Magnetism, by A. W. Hirst. xv+388 pp. New York, Prentice-Hall, Inc., 1937. $4.50.

Relativity

Relativity Theory of Protons and Electrons is the title of a highly entertaining new book by an author who needs no introduction, in which a theory is presented which aims to combine the concepts of the relativity and the quantum theories. The author has sought in his work to develop anew the theory of relativity along lines indicated by Diarc in his work which led to the relativistically invariant wave equation. The result has been, the author feels, an "harmonization rather than a unification" of the two theories.

The contents are divided into parts I and II, devoted in a general way to a development of the mathematical formalism and an application to physical problems respectively. This division, however, is a rather loose one since already in part I much physics has been anticipated. Part II concentrates itself largely about the problem of the origin of the "four required constants of nature:" (1) the ratio of the masses of the proton and the electron; (2) the fine structure constant; (3) the gravitational constant and (4) the number of particles in the universe. Numerical values are obtained for these in Chapters XII, XIV, XV and XVI, which appear to be in agreement with observation.

The book is important and desirable primarily because it presents this theory, much of which has been discussed earlier by the author in a series of papers in the Proceedings of the Royal Society, for the first time as a connected and homogeneous unit.—H. H. NIELSEN.

Relativity Theory of Protons and Electrons, by Sir Arthur Eddington. vi+ 336 pp. Cambridge, at the University Press; in New York, The Macmillan Co., 1936. $5.50.

Part Two of Peterson's Manual Completed

In 1934 Professor Alvah Peterson, of the Ohio State University, published Part I of his "Manual of Entomological Equipment and Methods." This first part dealt largely with equipment, most of which was diagramed, and with definite references to the sources. The extreme care and completeness with which Dr. Peterson prepared this first volume made it exceptionally valuable to all persons interested in any phase of entomology. Since its appearance entomologists have been eagerly awaiting the publication of Part II.

This second volume deals primarily with the rearing of insects. All of the literature upon this subject appearing in the English language has been consulted and abstracted under the names of the authors. One noteworthy feature of these abstracts is that they are of sufficient length to give a fairly comprehensive idea of the methods as described in the original articles. A second division of the volume gives twenty-one full page plates of special equipment as used in the articles abstracted. These are well drawn, clear and distinctly labelled. Besides rearing methods there has been included a number of related topics such as: killing, mounting, marking, shipping, etc.

To make the great mass of abstracts most usable the author has prepared a double index. Part A of this index is based upon the names of all the forms of insects, common and scientific, that are discussed in the abstracts. Part B is based upon the kinds of materials and equipment and the methods employed in the rearing. With the alphabetical arrangement of the authors this makes reference work very easy.

While either of these parts is of value to those working in special fields it is difficult to see how anyone working with insects can afford to be without the set of two volumes.—D. F. MILLER.

A Manual of Entomological Equipment and Methods, Part II, by Alvah Peterson. 334 pp. St. Louis, John S. Swift Co., Inc., 1937.